11.5 CWIS Impacts in the Great Lakes

The Great Lakes were carved out by glaciers during the last ice age (Bailey and Smith, 1981). They contain nearly 20% of the earth's fresh water, or about 23,000 km^3 (5,500 cu. mi.) of water, covering a total area of 244,000 km^2 (94,000 sq. mi.). There are five Great Lakes: Lake Superior, Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario. Although part of a single system, each lake has distinct characteristics. Lake Superior is the largest by volume, with a retention time of 191 years, followed by Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario.

Water temperatures in the Great Lakes strongly influence the physiological processes of aquatic organisms, affecting growth, reproduction, survival, and species temporal and spatial distribution. During the spring, many fish species inhabit shallow, warmer waters where temperatures are closer to their thermal optimum. As water temperatures increase, these species migrate to deeper water. For species that are near the northern limit of their range, the availability of shallow, sheltered habitats that warm early in the spring is probably essential for survival (Lane et al., 1996a). For other species, using warmer littoral areas increases the growing season and may significantly increase production.

Some 80 percent of Great Lakes fishes use the littoral zone for at least part of the year (Lane et al.,1996a). Of 139 Great Lakes fish species reviewed by Lane et al. (1996b), all but the deepwater ciscoes (*Coregonus* spp.) and deepwater sculpin (*Myxocephalus thompsoni*) use waters less than 10 m deep as nursery habitat.

A large number of thermal-electric plants located on the Great Lakes draw their cooling water from the littoral zone, resulting in high I&E of several fish species of commercial, recreational, and ecological importance, including alewife, gizzard shad, yellow perch, rainbow smelt , and lake trout (Tables 11-6 to 11-9).

The I&E estimates of Kelso and Milburn (1979) presented in Tables 11-7 and 11-9 were derived using methods that differed in a number of ways from EPA's estimation methods, and therefore the data are not strictly comparable. First, the Kelso and Milburn (1979) data represent total annual losses per lake, whereas EPA's estimates are on a per facility basis. In addition, the estimates of Kelso and Milburn (1979) are based on extrapolation of losses to facilities for which data were unavailable using regression equations relating losses to plant size.

Despite the differences in estimation methods, when converted to an annual average per facility, the impingement estimates of Kelso and Milburn (1979) are within the range of EPA's estimates. For example, average annual impingement is 675,980 fish per facility based on Kelso and Milburn's (1979) data is comparable to EPA's high estimate of 1,470,000 for alewife.

On the other hand, EPA's entrainment estimates include egg losses and are therefore substantially larger than those of Kelso and Milburn (1979). Because of the high natural mortality of fish eggs, EPA's inclusion of all egg losses likely overestimates entrainment, as noted in Section 11.2.2. However, by omitting all egg losses, the entrainment estimates of Kelso and Milburn (1979) are likely to underestimate losses. Viewed together, the two types of estimates give an indication of the possible upper and lower bounds of annual entrainment losses per facility (e.g., an annual average of 8,018,657 fish based on Kelso and Milburn's data compared to EPA's highest estimate of 526,000,000 based on the average for alewife) .

Table 11-6: Annual Entrainment of Eggs, Larvae and Juvenile Fish in the Great Lakes

Common Name	Scientific Name	Number of Facilities	Mean Annual Entrainment per Facility (fish/year)	Range
alewife	*Alosa pseudoharengus*	5	526,000,000	3,930,000 - 1,360,000,000
rainbow smelt	*Osmerus mordax*	5	90,500,000	424,000 - 438,000,000
lake trout	*Salmo namaycush*	1	116,000	---

Sources: Texas Instruments Inc., 1978; Michaud, 1998.

Table 11-7: Annual Entrainment of Larval Fish in the Great Lakes by Lake		
Lake	Number of Facilities	Total Annual Entrainment (fish/year)
Erie	16	255,348,164
Michigan	25	196,307,405
Ontario	11	176,285,758
Huron	6	81,462,440
Superior	14	4,256,707

Source: Kelso and Milburn, 1979.

Table 11-8: Annual Impingement in the Great Lakes for All Age Classes Combined				
Common Name	Scientific Name	Number of Facilities	Mean Annual Impingement per Facility (fish/year)	Range
alewife	*Alosa pseudoharengus*	15	1,470,000	355 - 5,740,000
gizzard shad	*Dorosoma cepedianum*	6	185,000	25 - 946,000
rainbow smelt	*Osmerus mordax*	15	118,000	78 - 549,000
threespine stickleback	*Gasterosteus aculeatus*	3	60,600	23,200 - 86,200
yellow perch	*Perca flavescens*	9	29,900	58 - 127,000
spottail shiner	*Notropis hudsonius*	8	22,100	5 - 62,000
freshwater drum	*Aplodinotus grunniens*	4	18,700	2 - 74,800
emerald shiner	*Notropis atherinoides*	4	7,250	3 - 28,600
trout perch	*Percopsis omiscomaycus*	5	5,630	30 - 23,900
bloater	*Coregonus hoyi*	2	4,980	3,620 - 6,340
white bass	*Morone chrysops*	1	4,820	--
slimy sculpin	*Cottus cognatus*	4	3,330	795 - 5,800
goldfish	*Carassius auratus*	3	2,620	4 - 7,690
mottled sculpin	*Cottus bairdi*	3	1,970	625 - 3,450
common carp	*Cyprinus carpio*	4	1,110	16 - 4,180
pumpkinseed	*Lepomis gibbosus*	4	1,060	14 - 3,920

Sources: Benda and Houtcooper, 1977; Sharma and Freeman, 1977; Texas Instruments Inc., 1978; Thurber and Jude, 1985; Lawler Matusky & Skelly Engineers, 1993; Michaud, 1998.

Table 11-9: Annual Impingement of Fish in the Great Lakes

Lake	Number of Facilities	Total Annual Impingement (fish/year)
Erie	16	22,961,915
Michigan	25	15,377,339
Ontario	11	14,483,271
Huron	6	7,096,053
Superior	14	243,683

Source: Kelso and Milburn, 1979.

11.6 CWIS Impacts in Estuaries

Estuaries are semi-enclosed bodies of water that have a an unimpaired natural connection with the open ocean and within which sea water is diluted with fresh water derived from land. Estuaries are created and sustained by dynamic interactions among oceanic and freshwater environments, resulting in a rich array of habitats used by both terrestrial and aquatic species (Day et al., 1989). Because of the high biological productivity and sensitivity of estuaries, EPA's regulatory framework imposes more stringent compliance requirements on CWIS located in estuaries than on those located in other waterbody types.

Numerous commercially, recreationally, and ecologically important species of clams, crustaceans, and fish spend part or all of their life cycle within estuaries. Marine species that spawn offshore take advantage of prevailing inshore currents to transport their eggs, larvae, or juveniles into estuaries where they hatch or mature. Inshore areas along the edges of estuaries support high rates of primary productivity and are used by numerous aquatic and terrestrial species for nesting, feeding, and resting, or as nursery habitats or shelter. This high level of biological productivity makes these shallow littoral zone habitats highly susceptible to I&E impacts from CWIS.

Estuarine species that show the highest rates of I&E in the studies reviewed by EPA include bay anchovy (*Anchoa mitchilli*), tautog (*Tautoga onitis*), Atlantic menhaden (*Brevoortia tyrannus*), gulf menhaden (*Brevoortia patronus*), winter flounder (*Pleuronectes americanus*), and weakfish (*Cynoscion regalis*) (Tables 11-10 and 11-11).

During spring, summer and fall, various life stages of these and other estuarine fishes show considerable migratory activity. Adults move in from the ocean to spawn in the marine, brackish, or freshwater portions of estuaries or their associated rivers; the eggs and larvae can be planktonic and move about with prevailing currents or by using selective tidal transport; juveniles actively move upstream or downstream in search of optimal nursery habitat; and young adult anadromous fish move out into the ocean to reach sexual maturity.

Because of this high degree of migratory activity, a CWIS located in an estuary not only harms indigenous fish species and local food webs, but also directly affects adult or juvenile anadromous fish and indirectly affects marine food webs that depend on these fish. As a result, EPA's proposed regulatory framework seeks to discourage placement of a CWIS anywhere in an estuary.

Table 11-10: Annual Entrainment of Eggs, Larvae, and Juvenile Fish in Estuaries				
Common Name	Scientific Name	Number of Facilities	Mean Annual Entrainment per Facility (fish/year)	Range
bay anchovy	*Anchoa mitchilli*	2	18,300,000,000	12,300,000,000 - 24,400,000,000
tautog	*Tautoga onitis*	1	6,100,000,000	---
Atlantic menhaden	*Brevoortia tyrannus*	2	3,160,000,000	50,400,000 - 6,260,000,000
winter flounder	*Pleuronectes americanus*	1	952,000,000	---
weakfish	*Cynoscion regalis*	2	339,000,000	99,100,000 - 579,000,000
hogchoker	*Trinectes maculatus*	1	241,000,000	---
Atlantic croaker	*Micropogonias undulatus*	1	48,500,000	---
striped bass	*Morone saxatilis*	4	19,200,000	111,00 - 74,800,000
white perch	*Morone americana*	4	16,600,000	87,700 - 65,700,000
spot	*Leiostomus xanthurus*	1	11,400,000	---
blueback herring	*Alosa aestivalis*	1	10,200,000	---
alewife	*Alosa pseudoharengus*	1	2,580,000	---
Atlantic tomcod	*Microgadus tomcod*	3	2,380,000	2,070 - 7,030,000
American shad	*Alosa sapidissima*	1	1,810,000	---

Sources: U.S. EPA, 1982; Lawler Matusky & Skelly Engineers, 1983; DeHart, 1994; PSE&G, 1999.

Table 11-11: Annual Impingement in Estuaries for All Age Classes Combined				
Common Name	Scientific Name	Number of Facilities	Mean Annual Impingement per Facility (fish/year)	Range
gulf menhaden	*Brevoortia patronus*	2	76,000,000	2,990,000 - 149,000,000
smooth flounder	*Liopsetta putnami*	1	3,320,000	--
threespine stickleback	*Gasterosteus aculeatus*	4	866,000	123 - 3,460,000
Atlantic menhaden	*Brevoortia tyrannus*	12	628,000	114 - 4,610,000
rainbow smelt	*Osmerus mordax*	4	510,000	737 - 2,000,000
bay anchovy	*Anchoa mitchilli*	9	450,000	1,700 - 2,750,000
weakfish	*Cynoscion regalis*	4	320,000	357 - 1,210,000
Atlantic croaker	*Micropogonias undulatus*	8	311,000	13 - 1,500,000
spot	*Leiostomus xanthurus*	10	270,000	176 - 647,000
blueback herring	*Alosa aestivalis*	7	205,000	1,170 - 962,000
white perch	*Morone americana*	14	200,000	287 - 1,380,000
threadfin shad	*Dorosoma petenense*	1	185,000	---
lake trout	*Salmo namaycush*	1	162,000	---
gizzard shad	*Dorosoma cepedianum*	6	125,000	2,058 - 715,000
silvery minnow	*Hybognathus nuchalis*	1	73,400	---

Sources: Consolidated Edison Company of New York Inc., 1975; Lawler Matusky & Skelly Engineers, 1975, 1976; Stupka and Sharma, 1977; Lawler et al., 1980; Texas Instruments Inc., 1980; Van Winkle et al., 1980; Consolidated Edison Company of New York Inc. and New York Power Authority, 1983; Normandeau Associates Inc., 1984; EA Science and Technology, 1987; Lawler Matusky & Skelly Engineers, 1991; Richkus and McClean, 1998; PSE&G, 1999; New York State Department of Environmental Conservation, No Date.

11.7 CWIS Impacts in Oceans

Oceans are marine open coastal waters with salinity greater than or equal to 30 parts per thousand. CWIS in oceans are usually located over the continental shelf, a shallow shelf that slopes gently out from the coastline an average of 74 km (46 miles) to where the sea floor reaches a maximum depth of 200 m (660 ft) (Ross, 1995). The deep ocean extends beyond this region. The area over the continental shelf is known as the Neritic Province and the area over the deep ocean is the Oceanic Province (Meadows and Campbell, 1978).

Vertically, the upper, sunlit epipelagic zone over the continental shelf averages about 100 m in depth (Meadows and Campbell, 1978). This zone has pronounced light and temperature gradients that vary seasonally and influence the temporal and spatial distribution of marine organisms.

In oceans, the littoral zone encompasses the photic zone of the area over the continental shelf. As in other water body types, the littoral zone is where most marine organisms concentrate. The littoral zone of oceans is of particular concern in the context of §316(b) because this biologically productive zone is also where most coastal utilities withdraw cooling water. EPA's regulatory framework imposes more stringent standards for facilities with intakes located less than 100 m outside the coastal littoral zone.

The morphology of the continental shelf along the U.S. coastline is quite varied (NRC, 1993). Along the Pacific coast of the United States the continental shelf is relatively narrow, ranging from 5 to 20 km (3 to 12 miles), and is cut by several steep-sided submarine canyons. As a result, the littoral zone along this coast tends to be narrow, shallow, and steep. In contrast, along most of the Atlantic coast of the United States, there is a wide, thick, and wedge-shaped shelf that extends as much as 250 km (155 miles) from shore, with the greatest widths generally opposite large rivers. Along the Gulf coast, the shelf ranges from 20 to 50 km (12 to 31 miles).

Marine environments differ in several fundamental ways from freshwater environments. For example, they include much larger volumes of water, and pelagic life stages of aquatic organisms are more prevalent. Currents and tides play an important role in distributing pelagic organisms. One reproductive strategy used by marine fish and invertebrates species is to cast their offspring into the ocean currents to ensure wide geographic distribution. Planktonic life stages are therefore quite common. The abundance of plankton in temperate regions is seasonal, with greater numbers in spring and summer and fewer numbers in winter. The young of a number of invertebrate and fish species reproduce over the continental shelf. Prevailing currents and tides tend to carry these organisms back to nursery areas such as bays, estuaries, wetlands, or coastal rivers.

The potential for I&E can be high if CWIS are located in productive, shallow areas of oceans or in locations where tides bring in or aggregate plankton or migratory fish species. This effect is magnified because many marine species rely on drifting, planktonic life stages of their offspring to increase their dispersal potential over large volumes of water. An additional issue pertains to the presence of marine mammals and reptiles, including threatened and endangered species of sea turtles. These species are known to enter submerged offshore CWIS and can drown once inside the intake tunnel.

In addition to many of the species discussed in the section on estuaries, other fish species found in near coastal waters that are of commercial, recreational, or ecological importance and are particularly vulnerable to I&E include silver perch (*Bairdiella chrysura*), cunner (*Tautogolabrus adspersus*), several anchovy species, scaled sardine (*Harengula jaguana)*, and queenfish (*Seriphus politus*) (Tables 11-12 and 11-13).

Table 11-12: Annual Entrainment of Eggs, Larvae, and Juvenile Fish in Oceans

Common Name	Scientific Name	Number of Facilities	Mean Annual Entrainment per Facility (fish/year)	Range
bay anchovy	*Anchoa mitchilli*	2	44,300,000,000	9,230,000,000 - 79,300,000,000
silver perch	*Bairdiella chrysura*	2	26,400,000,000	8,630,000 - 52,800,000,000
striped anchovy	*Anchoa hepsetus*	1	6,650,000,000	---
cunner	*Tautogolabrus adspersus*	2	1,620,000,000	33,900,000 - 3,200,000,000
scaled sardine	*Harengula jaguana*	1	1,210,000,000	---
tautog	*Tautoga onitis*	2	911,000,000	300,000 - 1,820,000,000
clown goby	*Microgobius gulosus*	1	803,000,000	---
code goby	*Gobiosoma robustum*	1	680,000,000	---
sheepshead	*Archosargus probatocephalus*	1	602,000,000	---
kingfish	*Menticirrhus* spp.	1	542,000,000	---
pigfish	*Orthopristis chrysoptera*	2	459,000,000	755,000 - 918,000,000
sand sea trout	*Cynoscion arenarius*	1	325,000,000	---
northern kingfish	*Menticirrhus saxatilis*	1	322,000,000	---
Atlantic mackerel	*Scomber scombrus*	1	312,000,000	---
Atlantic bumper	*Chloroscombrus chrysurus*	1	298,000,000	---

Sources: Conservation Consultants Inc., 1977; Stone & Webster Engineering Corporation, 1980; Florida Power Corporation, 1985; Normandeau Associates, 1994; Jacobsen et al., 1998; Northeast Utilities Environmental Laboratory, 1999.

Table 11-13: Annual Impingement in Oceans for All Age Classes Combined

Common Name	Scientific Name	Number of Facilities	Mean Annual Impingement per Facility (fish/year)	Range
queenfish	*Seriphus politus*	2	201,000	19,800 - 382,000
polka-dot batfish	*Ogcocephalus radiatus*	1	74,500	---
bay anchovy	*Anchoa mitchilli*	2	49,500	11,000 - 87,900
northern anchovy	*Engraulis mordax*	2	36,900	26,600 - 47,200
deepbody anchovy	*Anchoa compressa*	2	35,300	34,200 - 36,400
spot	*Leiostomus xanthurus*	1	28,100	---
American sand lance	*Ammodytes americanus*	2	20,700	886 - 40,600
silver perch	*Bairdiella chrysura*	2	20,500	12,000 - 29,000
California grunion	*Caranx hippos*	1	18,300	---
topsmelt	*Atherinops affinis*	2	18,200	4,320 - 32,300
alewife	*Alosa pseudoharengus*	2	16,900	1,520 - 32,200
pinfish	*Lagodon rhomboides*	1	15,200	---
slough anchovy	*Anchoa delicatissima*	3	10,900	2,220 - 27,000
walleye surfperch	*Hyperprosopon argenteum*	1	10,200	---
Atlantic menhaden	*Brevoortia tyrannus*	3	7,500	861 - 20,400

Sources: Stone & Webster Engineering Corporation, 1977; Stupka and Sharma, 1977; Tetra Tech Inc., 1978; Stone and Webster Engineering Corporation, 1980; Florida Power Corporation, 1985; Southern California Edison Company, 1987; SAIC, 1993; EA Engineering, Science and Technology, 1997; Jacobsen et al., 1998.

11.8 Summary of I&E Data

The data evaluated by EPA indicate that fish species with free-floating, early life stages are those most susceptible to CWIS impacts. Such planktonic organisms lack the swimming ability to avoid being drawn into intake flows. Species that spawn in nearshore areas, have planktonic eggs and larvae, and are small as adults experience even greater impacts because both new recruits and the spawning adults are affected (e.g., bay anchovy in estuaries and oceans).

EPA's data review also indicates that fish species in estuaries and oceans experience the highest rates of I&E. These species tend to have planktonic eggs and larvae, and tidal currents carry planktonic organisms past intakes multiple times, increasing the probability of I&E. In addition, fish spawning and nursery areas are located throughout estuaries and near coastal waters, making it difficult to avoid locating intakes in areas where fish are present.

11.9 Potential Benefits of §316(b) Regulation

11.9.1 Introduction: Benefits Concepts, Categories, and Causal Links

Valuing the changes in environmental quality that arise from the §316(b) regulations for new facilities is a principal desired outcome for the Agency's policy assessment framework. However, time and data constraints do not permit a quantified assessment of the economic benefits of the proposed rule. Nonetheless, this section provides a qualitative description of the types of benefits that are expected.

As noted in previous sections of this chapter, changes in CWIS design, location, or capacity can reduce I&E rates. These changes in I&E can potentially yield significant ecosystem improvements in terms of the number of fish that avoid premature mortality. This in turn is expected to increase local and regional fishery populations, and ultimately contribute to the enhanced environmental functioning of affected water bodies (rivers, lakes, estuaries, and oceans). Finally, the economic welfare of human populations is expected to increase as a consequence of the improvements in fisheries and associated aquatic ecosystem functioning. Below, we identify potential ecological outcomes and related economic benefits from anticipated reductions in adverse effects of CWIS. We explain the basic economic concepts applicable to the economic benefits, including benefit categories and taxonomies, service flows, and market and nonmarket goods and services.

11.9.2 Economic Benefit Categories Applicable to the §316(b) Rule

To estimate the economic benefits of minimizing I&E at new CWIS, all the beneficial outcomes need to be identified and, where possible, quantified and assigned appropriate monetary values. Estimating economic benefits can be challenging because of the many steps that need to be analyzed to link a reduction in I&E to changes in impacted fisheries and other aspects of relevant aquatic ecosystems, and to then link these ecosystem changes to the resulting changes in quantities and values for the associated environmental goods and services that ultimately are linked to human welfare.

Key challenges in benefits assessment include uncertainties and data gaps, as well as the fact that many of the goods and services beneficially affected by the proposed change in new facility I&E are not traded in the marketplace. Thus there are numerous instances — including this proposed §316(b) rule for new facilities — when it is not feasible to confidently assign monetary values to some beneficial outcomes. In such instances, benefits need to be described and considered qualitatively. This is the case for the proposed rule for new facility CWIS. At this time, there is only general information about the location of most proposed new facilities, and in most cases details of facility and environmental characteristics are unknown. As a result, it is not possible to do a detailed analysis of potential monetary benefits associated with the proposed regulations.

11.9.3 Benefit Category Taxonomies

The term "economic benefits" here refers to the dollar value associated with all the expected positive impacts of the §316(b) regulation being proposed for new facilities. Conceptually, the monetary value of benefits is the sum of the predicted changes in "consumer and producer surplus." These surplus measures are standard and widely accepted terms of applied welfare economics, and reflect the degree of well-being derived by economic agents (e.g., people or firms) given different levels of goods and services, including those associated with environmental quality.[3]

The economic benefits of activities that improve environmental conditions can be categorized in many different ways. The various terms and categories offered by

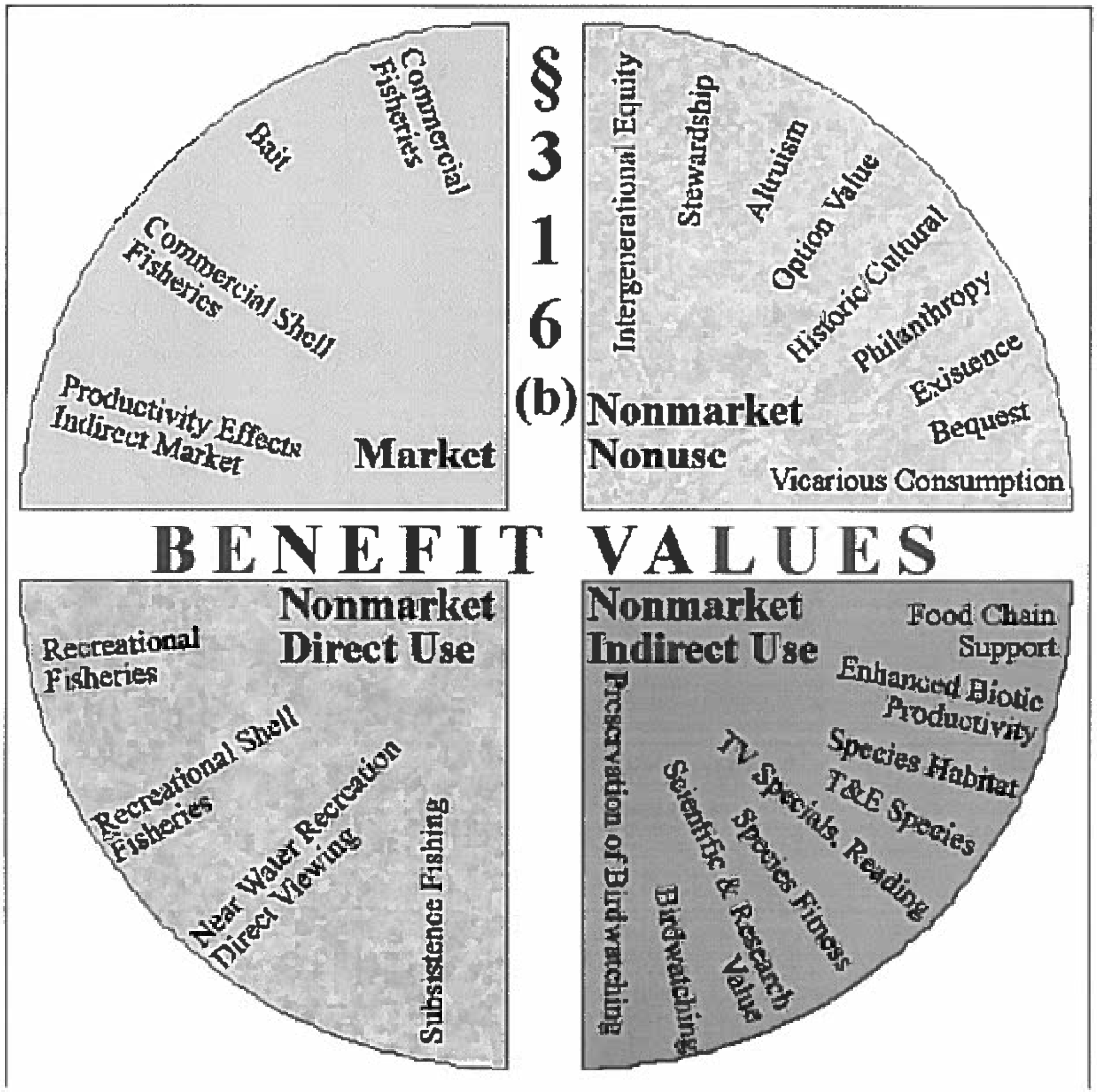
[3] Technically, consumer surplus reflects the difference between the "value" an individual places on a good or service (as reflected by the individual's "willingness to pay" for that unit of the good or service) and the "cost" incurred by that individual to acquire it (as reflected by the "price" of a commodity or service, if it is provided in the marketplace). Graphically, this is the area bounded from above by the demand curve and below by the market clearing price. Producer surplus is a similar concept, reflecting the difference between the market price a producer can obtain for a good or service and the actual cost of producing that unit of the commodity.

different authors can lead to some confusion with semantics. However, the most critical issue is to try not to omit any relevant benefit, and at the same time avoid potential double counting of benefits.

One common typology for benefits of environmental programs is to divide them into three main categories of (1) economic welfare (e.g., changes in the well-being of humans who derive use value from market or nonmarket goods and services such as fisheries); (2) human health (e.g., the value of reducing the risk of premature fatality due to changing exposure to environmental exposure); and (3) nonuse values (e.g., stewardship values for the desire to preserve threatened and endangered species). For the §316(b) regulation, however, this typology does not convey all the intricacies of how the rule might generate benefits. Further, human health benefits are not anticipated. Therefore, another categorization may be more informative.

Figure 11-1 outlines the most prominent categories of benefit values for the §316(b) rule. The four quadrants are divided by two principles: (1) whether the benefit can be tracked in a market (i.e., market goods and services) and (2) how the benefit of a nonmarket good is received by human beneficiaries (either from direct use of the resource, from indirect use, or from nonuse).

Figure 11-1: §316(b) Benefit Values



Market benefits are best typified by commercial fisheries, where a change in fishery conditions will manifest itself in the price, quantity, and/or quality of fish harvests. The fishery changes thus result in changes in the marketplace, and can be evaluated based on market exchanges.

Direct use benefits include the value of improved environmental goods and services used and valued by people (whether or not they are traded in markets). A typical nonmarket direct use would be recreational angling, in which participants enjoy a welfare gain when the fishery improvement results in a more enjoyable angling experience (e.g., higher catch rates).

Indirect use benefits refer to changes that contribute, through an indirect pathway, to an increase in welfare for users (or nonusers) of the resource. An example of an indirect benefit would be when the increase in the number of forage fish enables the population of valued predator species to improve (e.g., when the size and numbers of prized recreational or commercial fish increase because their food source has been improved). In such a context, the I&E impacts on a forage species will indirectly result in welfare gains for recreational or commercial anglers.

Nonuse benefits — also known as passive use values — reflect the values individuals assign to improved ecological conditions apart from any current, anticipated, or optional use by them. Some economists consider option values to be a part of nonuse values because the option value is not derived from actual current use, whereas other writers place it in a use category (because the option value is associated with preserving opportunity for a future use of the resource). For convenience, we place option value in the nonuse category.

11.9.4 Direct Use

Direct use benefits are the simplest to envision. The welfare of commercial, recreational, and subsistence fishermen is improved when fish stocks increase and their catch rates rise. This increase in stocks may be induced by reduced I&E of species sought by fishermen, or through reduced I&E of forage and bait fish, which leads to increases in populations of commercial and recreational species. For subsistence fishermen, the increase in fish stocks may reduce the amount of time spent fishing for their meals or increase the number of meals they are able to catch. For recreational anglers, more fish and higher catch rates may increase the enjoyment of a fishing trip and may also increase the number of fishing trips taken. For commercial fishermen, larger fish stocks may lead to increased revenues through increases in total landings and/or increases in the catch per unit of effort (i.e., lower costs per fish caught). Increases in catch may also lead to growth in related commercial enterprises, such as commercial fish cleaning/filleting, commercial fish markets, recreational charter fishing, and fishing equipment sales.

Evidence that these use benefits are valued by society can be seen in the market. For example, in 1996 about 35 million recreational anglers spent nearly $38 billion on equipment and fishing trip related expenditures (US DOI, 1997) and the 1996 GDP from fishing, forestry, and agricultural services (not including farms) was about $39 billion (BEA, 1998). Clearly, these data indicate that the fishery resource is very important. These baseline values do not give us a sense of how benefits change with changes in environmental quality such as reduced I&E and increased fish stocks. However, even a change of 0.1% would translate into potential benefits of $40 million per year.

Commercial fishermen. The benefits derived from increased landings by commercial fishermen can be valued by looking at the market in which the fish are sold. The ideal measure of commercial fishing benefits is the producer surplus generated by the marginal increase in landings, but often the data required to compute the producer surplus are unavailable. In this case, revenues may be used as a proxy for producer surplus, with some assumptions and an adjustment. The assumptions are that (1) there will be no change in harvesting behavior or effort, but existing commercial anglers will experience an increase in landings, and (2) there will be no change in price. Given these assumptions, benefits can be estimated by calculating the expected increase in the value of commercial landings, and then translating the landed values into estimated increases in producer surplus. The economic literature (Huppert, 1990) suggests that producer surplus values for commercial fishing have been estimated to be approximately 90% of total revenue (landings values are a close proxy for producer surplus because the commercial fishing sector has very high fixed costs relative to its variable costs). Therefore, the marginal benefit from an increase in commercial landings can be estimated to be approximately 90% of the anticipated change in revenue.

Recreational users. The benefits of recreational use cannot be tracked in the market. However, there is an extensive literature on valuing fishing trips and valuing increased catch rates on fishing trips. While it is likely that nearwater recreational users will gain benefits, It is unlikely that swimmers would perceive an important effect on their use of the ecosystem. Boaters may receive recreational value to the degree that enjoyment of their surroundings is an important part of their recreational pleasure or that fishing is a secondary reason for boating. Passive use values to these and other individuals are discussed below.

Primary studies of sites throughout the United States have shown that anglers value their fishing trips and that catch rates are one of the most important attributes contributing the quality of their trips.

Higher catch rates may translate into two components of recreational angling benefits: an increase in the value of existing recreational fishing trips, and an increase in recreational angling participation. The most promising approaches for quantifying and monetizing these two benefits components are benefits transfer (as a secondary method) and random utility modeling or RUM (as a primary research method).

To estimate the value of an improved recreational fishing experience, it is necessary to estimate the existing number of angling trips or days that are expected to be improved by reducing I&E. As with the commercial fishing benefits, it is important to identify the appropriate geographic scope when estimating these numbers. Once the existing angling numbers have been estimated, the economic value of an improvement (consumer surplus) can be estimated. The specific approach for estimating the value will depend on the economic literature that is most relevant to the specific characteristics of the study site. For example, some economic studies in the literature can be used to infer a factor (percentage increase) that can be applied to the baseline value of the fishery for specific changes in fishery conditions. Other primary studies simply provide an estimate of the incremental value attributable to an improvement in catch rate.

In some cases it may be reasonable to assume that increases in fish abundance (attributable to reducing I&E) will lead to an increase in recreational fishing participation. This would be particularly relevant in a location that has experienced such a severe impact to the fishery that the site is no longer an attractive location for recreational activity. Estimates of potential recreational activity post-regulation can be made based on similar sites with healthy fishery populations, on conservative estimates of the potential increase in participation (e.g., a 5% increase), or on recreational planning standards (densities or level of use per acre or stream mile). A participation model (as in a RUM application) could also be used to predict changes in the net addition to user levels from the improvement at an impacted site. The economic benefit of the increase in angling days then can be estimated using values from the economic literature for a similar type of fishery and angling experience.

Subsistence anglers. 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 angling economically or culturally important to a component of the community. In cases of Native American use of impacted fisheries, the value of an improvement can sometimes be inferred from settlements in similar legal cases (including natural resource damage assessments, or compensation agreements between impacted 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).

11.9.5 Indirect Use Benefits

Indirect use benefits refer to welfare improvements that arise for those individuals whose activities are enhanced as an indirect consequence of the fishery or habitat improvements generated by the proposed new facility standards for CWIS. For example, the rule's positive impacts on local fisheries may, through the intricate linkages in ecologic systems, generate an improvement in the population levels and/or diversity of bird species in an area. This might occur, for example, if the impacted fishery is a desired source of food for an avian species of interest. Avid bird watchers might thus 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 a legitimate but indirect consequence of the proposed rule's initial impact on fish.

There are many forms of potential indirect benefits. For example, a rule-induced improvement in the population of a forage fish species may not be of any direct consequence to recreational or commercial anglers. However, the increased presence of forage fish may well have an indirect affect on commercial and recreational fishing values because it enhances an important part of the food chain. Thus, direct improvements in forage species populations may well result in a greater number (and/or greater individual size) of those fish that are targeted by recreational or commercial anglers. In such an instance, the relevant recreational and commercial fishery benefits would be an indirect consequence of the proposed rule's initial impacts on lower levels of the aquatic ecosystem.

The data and methods available for estimating indirect use benefits depend on the specific activity that is enhanced. For example, an indirect improvement to recreational anglers would be measured in essentially the same manner discussed under the preceding discussion on direct use benefits (e.g., using a RUM model). However, the analysis requires one additional critical step — that of indicating the link between the direct impact of the proposed rule (e.g., improvements in forage species populations) and the indirect use that is ultimately enhanced (e.g., the recreationally targeted fish). Therefore, what is typically required for estimating indirect use benefits is ecologic modeling that captures the key linkages between the initial impact of the rule and its ultimate (albeit indirect) effect on use values. In the example of forage species, the change in forage fish populations would need to be analyzed in a manner that ultimately yields information on responses in recreationally targeted species (e.g., that can be linked to a RUM analysis).

11.9.6 Nonuse Benefits

Nonuse (passive use) benefits arise when individuals value improved environmental quality apart from any past, present, or anticipated future use of the resource in question. Such passive use values have been categorized in several ways in the economic literature, typically embracing the concepts of existence (stewardship) and bequest (intergenerational equity) motives. Passive use values also may include the concept that some ecological services are valuable apart from any human uses or motives. Examples of these ecological services may include improved reproductive success for aquatic and terrestrial wildlife, increased diversity of aquatic and terrestrial wildlife, and improved conditions for recovery of threatened and endangered species.

Passive values can only be estimated in primary research through the use of direct valuation techniques such as contingent valuation method (CVM) surveys and related techniques (e.g., conjoint analysis using surveys). In the case of the §316(b) proposed new facilities rule, benefits transfer is used, with appropriate care and caveats clearly recognized.

One typical approach for estimating passive values is to apply a ratio between certain use-related benefits estimates and the passive use values anticipated for the same site and resource change. Freeman (1979) applied a rule of thumb in which he inferred that national-level passive benefits of water quality improvements were 50% of the estimated recreational fishing benefits. This was based on his review of the literature in those instances where nonuse and use values had been estimated for the same resource and policy change. Fisher and Raucher (1984) undertook a more in-depth and expansive review of the literature, found a comparable relationship between recreational angling benefits and nonuse values, and concluded that since nonuse values were likely to be positive, applying the 50% "rule of thumb" was preferred over omitting nonuse values from a benefits analysis entirely.

The 50% rule has since been applied frequently in EPA water quality benefits analyses (e.g., effluent guidelines RIAs for the iron and steel and pulp and paper sectors, and the RIA for the Great Lakes Water Quality Guidance). At times the rule has been extended to ratios higher than 50% (based on specific studies in the literature). However, the overall reliability and credibility of this type of approach is, as for any benefits transfer approach, dependent on the credibility of the underlying study and the comparability in resources and changes in conditions between the research survey and the §316(b) rule's impacts at selected sites. The credibility of the nonuse value estimate also is contingent on the reliability of the recreational angling estimates to which the 50% rule is applied.

A second approach to deriving estimates for §316(b) passive use values is to use benefits transfer to apply an annual willingness-to-pay estimate per nonuser household (e.g., Mitchell and Carson, 1986; Carson and Mitchell, 1993) to all the households with passive use motives for the impacted waterbody. The challenges in this approach include defining the appropriate "market" for the impacted site (e.g., what are the boundaries for defining how many households apply), as well as matching the primary research scenario (e.g., "boatable to fishable") to the predicted improvements at the §316(b)-impacted site.

For specific species, some valuation may be deduced using restoration-based costs as a proxy for the value of the change in stocks (or for threatened and endangered species the value of preserving the species). Where a measure of the approximate cost per individual can be deduced, and the number of individuals spared via BTA can be estimated, this may be a viable approach.

Table 11-14: Summary of Benefit Categories, Data Needs, Potential Data Sources, and Approaches		
Benefits Category	**Basic Data Needs**	**Potential Data Sources/Approaches**
Direct Use, Marketed Goods		
Increased commercial landings (fishing, shellfishing, & aquaculture)	▯ Estimated change in landings ▯ Estimated producer surplus	▯ Based on ecological modeling ▯ Based on available literature or 50% rule
Direct Use, Nonmarket Goods		
Improved value of a recreational fishing experience	▯ Estimated number of affected anglers ▯ Value of an improvement in catch rate, and possibly, value of an angling day	▯ Site-specific studies, national or statewide surveys ▯ Based on available literature
Increase in recreational fishing participation	▯ Estimated number of affected anglers or estimate of potential anglers ▯ Value of an angling day	▯ Site-specific studies, national or statewide surveys ▯ Based on available literature
Increase in subsistence fishing	▯ Estimated number of affected anglers or estimate of potential anglers ▯ Value of an angling day	▯ Site-specific studies, national or statewide surveys ▯ Based on available literature
Nonuse and Indirect Use, Nonmarketed		
Increase in indirect values	▯ Estimated changes in ecological services (e.g., reproductive success of aquatic species) ▯ Restoration based on costs	▯ Based on ecological modeling ▯ Site-specific studies, national or statewide surveys
Increase in passive use values	▯ Apply 50% rule to recreational fishing values	▯ Or use site-specific studies, national or statewide surveys

11.9.7 Summary of Benefits Categories

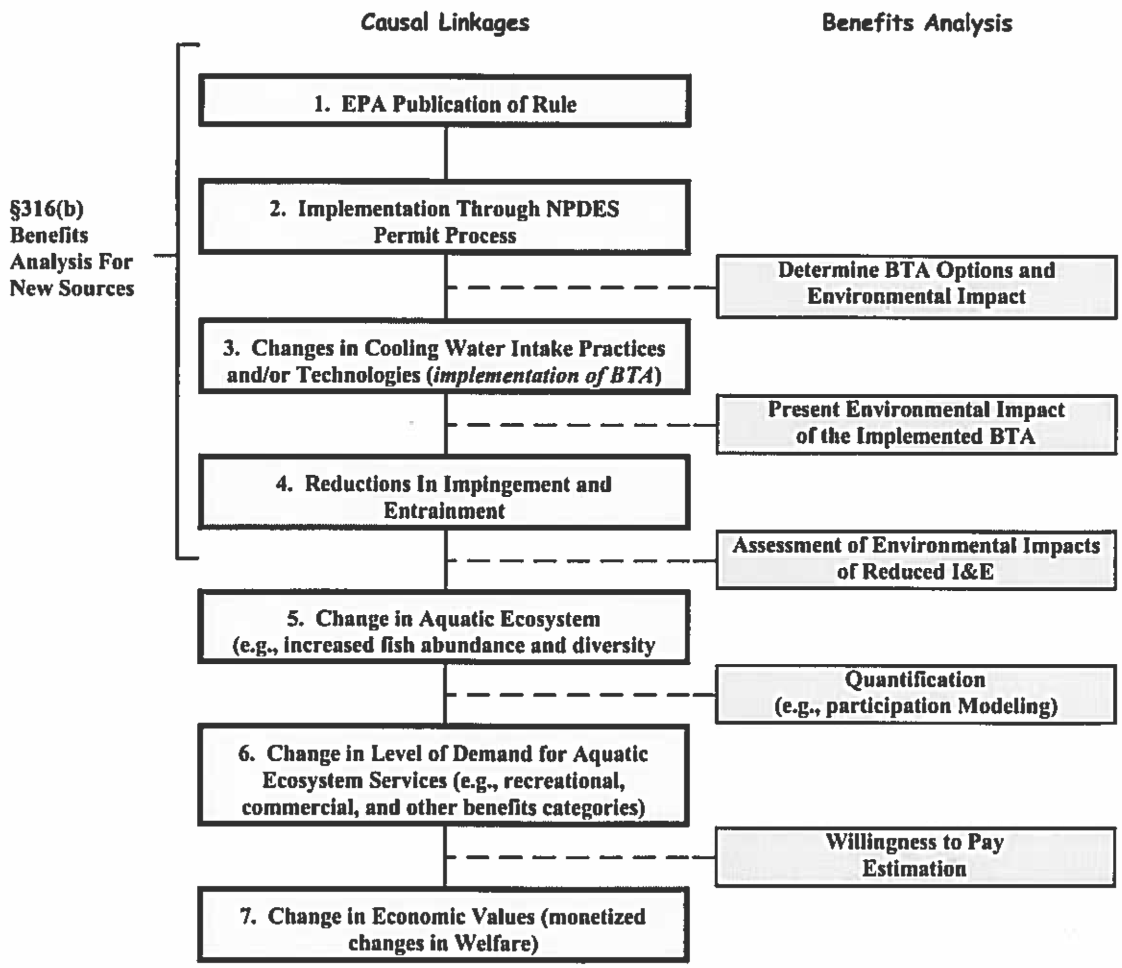
Table 11-4 displays the types of benefits categories expected to be affected by the §316(b) rule and the various data needs, data sources, and estimation approaches associated with each category. As described in sections 11.9.4 to 11.9.6, economic benefits can be broadly defined according to three categories: 1) direct use, 2) indirect use, and 3) nonuse (passive use) benefits. These benefits can be further categorized according to whether or not they are traded in the market. As indicated in Table 11-4 , "direct use" benefits include both "marketed" and "nonmarketed" goods, whereas "nonuse" and "indirect use" benefits include only "nonmarketed" goods.

11.9.8 Causality: Linking the §316(b) Rule to Beneficial Outcomes

Understanding the anticipated economic benefits arising from changes in I&E requires understanding a series of physical and socioeconomic relationships linking the installation of Best Technology Available (BTA) to changes in human behavior and values. As shown in Figure 11-2, these relationships span a broad spectrum, including institutional relationships to define BTA (from policy making to field implementation), the technical performance of BTA, the population dynamics of the aquatic ecosystems affected, and the human responses and values associated with these changes.

The first two steps in Figure 11-2 reflect the institutional aspects of implementing the §316(b) rule. In step 3, the anticipated applications of BTA (or a range of BTA options) must be determined for the regulated entities. This technology forms the basis for estimating the cost of compliance, and provides the basis for the initial physical impact of the rule (step 4). Hence, the analysis must predict how implementation of BTAs (as predicted in step 3) translates into changes in I&E at the regulated CWIS (step 4). These changes in I&E then serve as input for the ecosystem modeling (step 5).

Figure 11-2: Casual Linkages in the Benefits Analysis



In moving from step 4 to step 5, the selected ecosystem model (or models) are used to assess the change in the aquatic ecosystem from the preregulatory baseline (e.g., losses of aquatic organisms before BTA) to the postregulatory conditions (e.g., losses after BTA implementation). The potential output from these steps includes estimates of reductions in I&E rates, and changes in the abundance and diversity of aquatic organisms of commercial, recreational, ecological, or cultural value, including threatened and endangered species.

In step 6, the analysis involves estimating how the changes in the aquatic ecosystem (estimated in step 5) translate into changes in level of demand for goods and services. For example, the analysis needs to establish links between improved fishery abundance, potential increases in catch rates, and enhanced participation. Then, in step 7, as an example, the value of the increased enjoyment realized by recreational anglers is estimated. These last two steps typically are the focal points of the economic benefits portion of the analysis. However, because of data and time constraints, this benefits analysis is limited to only the first four steps of the process.

11.10 Empirical Indications of Potential Benefits

The following discussion provides examples from existing facilities that offer some indication of the relative magnitude of monetary benefits that may be expected to result from the proposed new facility regulations.

The potential benefits of lower intake flows and 100% recirculation of flow are illustrated by comparisons of once-through and closed-cycle cooling (e.g., Brayton Point and Hudson River facilities). The potential benefits of additional requirements defined by regional permit directors are demonstrated by operational changes implemented to reduce impingement and entrainment (e.g., Pittsburg and Contra Costa facilities). The potential benefits of reducing losses of forage species are demonstrated by analysis of the biological and economic relationships among forage species and commercial and recreational fishery species (e.g., Ludington facility on Lake Michigan). Finally, the potential benefits of implementing additional technologies to increase survival of organisms impinged or entrained are illustrated by the application of modified intake screens and fish return systems (e.g., Salem Nuclear Generating Facility). These cases are discussed below.

An example of the potential benefits of minimizing intake flow is provided by data for the Brayton Point facility, located on Mt. Hope Bay in Massachusetts (NEPMRI, 1981, 1995; U.S. EPA, 1982). In the mid-1980's, the operation of Unit 4 at Brayton Point was changed from closed-cycle to once-through cooling, increasing flow by 48% from an average of 703 MGD before conversion to an average of 1045 MGD for the first 6 years post-conversion (Lawler, Matusky, and Skelly Engineers, 1993). Although conversion to once-through cooling increased coolant flow and the associated heat load to Mt. Hope Bay, the facility requested the change because of electrical problems associated with Unit 4's saltwater spray cooling system (U.S. EPA, 1982). Comparison of I&E losses before and after the change provides a means of estimating the potential reduction in losses under closed cycle operation. Data on I&E losses following conversion of Unit 4 to once-through cooling are available in reports giving predicted (NEPMRI, 1981) or actual (Gibson, 1996) losses. Based on data for four species, EPA estimated that the annual reduction in entrainment losses of adult-equivalents of catchable fish under closed-cycle cooling would range from 7,250 for weakfish and 20,198 for tautog to 155,139 for winter flounder and 207,254 for Atlantic menhaden. Assuming that this would result in a proportional change in harvest, this represents an increase under closed cycle operation of 330,000 to 2 million pounds per year in commercial landings and from 42,000 to 128,000 pounds per year in recreational landings for these four species alone.

Another example of the potential benefits of low intake flow is provided by an analysis of I&E losses at five Hudson River power plants. Estimated fishery losses under once-through compared to closed-cycle cooling indicated that an average reduction in intake flow of about 95% at the three facilities responsible for the greatest impacts would result in a 30-80% reduction in fish losses, depending on the species involved (Boreman and Goodyear, 1988). An economic analysis estimated monetary damages under once-through cooling based on the assumption that annual percent reductions in year classes of fish result in proportional reductions in fish stocks and harvest rates (Rowe et al., 1995). A low estimate of per facility damages was based on losses at all five facilities and a high estimate was based on losses at the three facilities that account for most of the impacts. Damage estimates under once-through cooling ranged from about $1.3 million to $6.1 million annually in 1999 dollars.

Another example demonstrates how I&E losses of forage species can lead to reductions in economically valued species. Jones and Sung (1993) applied a RUM to estimate fishery impacts of I&E by the Ludington Pumped-Storage plant on Lake Michigan. This method estimates changes in demand as a function of changes in catch rates. The Ludington facility is responsible for the loss of about 1-3% of the total Lake Michigan production of alewives, a forage species that supports valuable trout and salmon fisheries. Jones and Sung (1993) estimated that losses of alewife result in a loss of nearly 6% of the angler catch of trout and salmon each year. Based on RUM analysis, they estimated that if Ludington operations ceased, catch rates of trout and salmon species would increase by 3.3 to 13.7 percent annually, amounting to an estimated recreational angling benefit of $0.95 million per year (in 1999 dollars) for these species alone.

Another example indicates the potential benefits of operational BTA that may be required by regional permit directors. Two plants in the San Francisco Bay/Delta, Pittsburg and Contra Costa, have made changes to their intake operations to reduce I&E of striped bass (*Morone saxatilis*). This also reduces incidental take of several threatened and endangered fish species, including the delta smelt (*Hypomesus transpacificus*) and several runs of chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). According to technical reports by the facilities, operational BTA has reduced striped bass losses by 78-94%, representing an increase in striped bass recreational landings of about 15,000 fish each year. A local study estimated that the consumer surplus of an additional striped bass caught by a recreational angler is $8.87 to $13.77 in 1999 dollars (Huppert, 1989). This implies a benefit to the recreational fishery, from reduced I&E of striped bass alone, in the range of $131,000 to $204,000 annually.

A final example indicates the benefits of technologies that can be applied to maximize survival. At the Salem Nuclear Generating Station in Delaware Bay, the facility's original intake screens were replaced with modified screens and improved fish return baskets that reduce impingement stress and increase survival of impinged fish (Ronafalvy et al., 1999). The changes resulted in an estimated 51% reduction in losses of weakfish. Assuming similar reductions in losses of other recreational and commercial species, this represents an increase in recreational landings of 13,000 to 65,000 fish per year and an increase in angler consumer surplus of as much as $269,000 annually in 1999 dollars. The estimated increase in commercial landings of 700 to 28,000 pounds per year represents an increase in producer surplus of up to $25,000 annually. Assuming that nonuse benefits are at least 50% of recreational use benefits, nonuse benefits associated with the screens may be expected to amount to up to $134,000 per year.

REFERENCES

Allan, J.D. 1995. *Stream Ecology, Structure and Function of Running Waters*. Chapman & Hall, New York.

Bailey, R.M., and G.E. Smith. 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Science* 38:1539–1561.

BEA, 1998. Bureau of Economic Analysis National Accounts Data: Gross Product by Industry. http://www.bea.doc.gov/bea/dn2/gpoc.htm

Benda, R.S. and W.C. Houtcooper. 1977.Impingement Studies at 16 Electric-Generating Plants in Michigan. In: Ecological Analysts Inc. Third National Workshop on Entrainment and Impingement: Section 316(b) - Research and Compliance. L.D. Jensen,-eds. Third National Workshop on Entrainment and Impingement: Section 316(b) - Research and Compliance, New York, NY. pp. 425.

Boreman, J. 1977. Impacts of Power Plant Intake Velocities on Fish. FWS/OBS-76/20.1, March 1977. U.S. Department of the Interior, Fish and Wildlife Service, Biological Services Program.

Boreman, J. and C.P. Goodyear. 1988. Estimates of entrainment mortality for striped bass and other fish species inhabiting the Hudson River Estuary. American Fisheries Society Monograph 4:152-160.

Carson, R.T. and R.C. Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water." Water Resources Research 29(7): 2445-2454.

Cherry D.A. and R.J. Currie. 1998. Effects of Impingement/Entrainment at the Kanawha River Plant on the Fish Community Structure of the Kanawha River: Reflections on the 20 Year Study. In: EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. Dixon, D. and K. Zammit (Ed.). Chorley, R.J., S.a. Schumm, and D.E. Sugden. 1984. Geomorphology. Methuen & Co., New York, NY.

Cincinnati Gas & Electric Company. 1979. 316(b) Demonstration, Walter C. Beckjord and Miami Fort Power Stations. Submitted to Ohio Environmental Protection Agency.

Cole, R.A. 1978. Entrainment at a Once-Through Cooling System on Western Lake Erie, Volume I. EPA-600/3-78-070. July.

Conservation Consultants Inc. 1977. Ecological Studies at Big Bend Steam Electric Station (Tampa Electric Company): An Analysis and Summary of Studies on the Effects of the Cooling Water System on Aquatic Fauna: A 316 Demonstration Biological Study. Volume III.

Consolidate Edison Company of New York Inc. 1975. Environmental Report to Accompany Application for Facility License Amendment for Extension of Operation with Once-Through Cooling for Indian Point Unit No. 2.

Consolidated Edison Company of New York Inc. and New York Power Authority. 1983. Hudson River Ecological Study in the Area of Indian Point: 1982 Annual Report.

Day, J.W., Jr., C.A.S. Hall, W.M. Kemp, and A. Yáñez-Arancibia. 1989. *Estuarine Ecology*. John Wiley & Sons, New York, NY.

DeHart, R.E. 1994. Brayton Point Station Technical Advisory Committee Meeting Summary, October 20, 1994.

EA Engineering, Science and Technology. 1997. Encina Power Plant Supplemental 316(b) Assessment Report. Final. Prepared for San Diego Gas & Electric.

EA Science and Technology. 1987. Final Report: Clifty Creek Station Impingement Study and Impact Assessment. Prepared for Indiana-Kentucky Electric Corporation. May. 46 pp.

Energy Impact Associates Inc. 1978. Fish Impingement and Entrainment Studies at Tanners Creek Power Plant: Final Report (Tanners Creek Plant Demonstration Document for P.L. 92-500 316(b), Volume II, Appendix B). Prepared for Indiana & Michigan Electric Company.

Fisher, A. and R.S. Raucher. 1984. Intrinsic benefits of improved water quality: Conceptual and empirical perspectives. *Advances in Applied Microeconomics* Vol. 3, V.K. Smith (ed.), JAI Press.

Florida Power Corporation. 1985. Crystal River Units 1, 2 and 3 316 Demonstration. Final Report - Appendix.

Freeman, A.M. 1979. "The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates." Council on Environmental Quality, Washington, D.C., December.

Freeman, R.F. and R.K. Sharma. 1977. Survey of Fish Impingement at Power Plants in the United States Volume II: Inland Waters. Prepared by Argonne National Laboratory. ANL/ES-56 Volume II. March. 323 pp.

Geo-Marine Inc. 1978. 316(b) Demonstration for the W. H. Sammis Generating Station. Prepared for Ohio Edison

Company. September 8. 122 pp.

Gibson, M. R. 1996. Comparison of Trends in the Finfish Assemblage of Mt. Hope Bay and Narragansett Bay in Relation to Operations at the New England Power Brayton Point Station. Report to the Brayton Point Technical Advisory Committee, August 1996. Rhode Island Division of Wildlife Research Reference Document 95/1.

Goldman, C.R., and A.R. Horne. 1983. *Limnology*. McGraw-Hill, Inc., New York, NY.

Goodyear, C.P. 1977. Mathematical methods to evaluate entrainment of aquatic organisms by power plants. FWS/OBS-76/20.3, U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C.

Goodyear, C.D. 1978. Evaluation of 316(b) Demonstration Detroit Edison's Monroe Power Plan. Administrative Report No. 83-3, Great Lakes Fishery Laboratory, U.S. Fish and Wildlife Service.

Goodyear, C.P. 1978. Entrainment impact estimates using the equivalent adult approach. FWS/OBS - 78/65, U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C.

Hicks, D.B. 1977. Statement of Findings for the Coleman Power Plant, Henderson, Kentucky. October 14. 5 pp.

Horst, T.J. 1975. The Equivalent Adult Model. A General Model for Fisheries Impact Assessment.

Huppert D.H. 1989. Measuring the value of fish to anglers: Application to central California anadromous species. Marine Resource Economics 6:89-107.

Huppert, D.D. 1990. "Economic Benefits from Commercial Fishing." draft report to National Marine Fisheries Service.

Hynes. H.B.N. 1970. *The Ecology of Running Water*. University of Toronto Press. 555 pp.

Jacobson P.M. E. Lorda D.J. Danilla J.D. Miller C.A. Tomichek and R.A. Sher. 1998. Studies of Cooling Water Intake Effects at Two Large Coastal Nuclear Power Stations in New England. In D. Dixon and K. Zammit (eds.) EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV.

Jones, C.A., and Y.D. Sung. 1993. Valuation of Environmental Quality at Michigan Recreational Fishing Sites: Methodological Issues and Policy Applications. Prepared under EPA Contract No. CR-816247 for the U.S. EPA, Washington, DC.

Kaplan, C.H. 2000. Personal communication to Martha Segall, Project Manager Tetra Tech, Inc., from Charles Kaplan, CK Environmental. April 18.

Kelso, J.R.M., and G.S. Milburn. 1979. Entrainment and impingement of fish by power plants in the Great Lakes which use the once-through cooling process. Journal of Great Lakes Research 5:182–194.

Lane, J.A., C.B. Portt, and C.K. Minns. 1996a. Habitat characteristics of adult fishes of the Great Lakes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2358.

Lane, J.A., C.B. Portt, and C.K. Minns. 1996b. Nursery habitat characteristics of Great Lakes fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2338.

Lawler J.P., W.T. Hogarth, B.J. Copeland, M.P. Weinstein, R.G. Hodson, and H.Y. Chen. 1980. Techniques for Assessing the Impact of Entrainment and Impingement as Applied to the Brunswick Steam Electric Plant. Pages 3-307 in L.D. Jensen (ed.) Paired Position Papers, Issues Associated with Impact Assessment: Proceedings of the Fifth National Workshop on Entrainment and Impingement. Ecological Analysts Inc. and Electric Power Research Institute, Palo Alto, CA.

Lawler, Matusky & Skelly Engineers. 1975. 1974 Hudson River Aquatic Ecology Studies - Bowline Point and Lovett Generating Stations. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1976. 1975 Hudson River Aquatic Ecology Studies - Bowline Point and Lovett Generating Stations: Vol. I: Chapters I-IX. Prepared for Orange and Rockland Utilities, Inc.

Lawler, Matusky & Skelly Engineers. 1983. 1979 and 1980 Data Analyses and Application of Empirical Models of Hudson River Fish Populations. Prepared for Consolidated Edison Company of New York, Inc. August.

Lawler, Matusky & Skelly Engineers. 1991. 1990 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities Inc.

Lawler, Matusky & Skelly Engineers. 1993. Population Dynamics of Winter Flounder in Mt. Hope Bay in Relation to Operations at the Brayton Point Electric Plant – A Review and Stock Assessment. Prepared for New England Power Company. September 1993.

Lawler, Matusky & Skelly Engineers. 1993. Impingement and Entrainment Study at Zion Nuclear Generating Station July 1991 - July 1993. Prepared for Commonwealth Edison Company. October.

Lewis R. and Seegert G. 1998. Entrainment and impingement studies at two powerplants on the Wabash

River in Indiana. In: EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. Dixon, D. and K. Zammit (Ed.).

Lohner, T. 1998. Fish Entrainment, Impingement, and Long-term Monitoring Studies at Ohio River Power Plants. Presentation at EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, 1998, Berkeley Springs, WV.

Matthews, W.J. 1998. Patterns in Freshwater Fish Ecology. Chapman & Hall, New York, NY.

Meadows, P.S., and J.I. Campbell. 1978. An Introduction to Marine Science. John Wiley and Sons, New York, NY.

Michaud D.T. 1998. Wisconsin Electric's Experience with Fish Impingement and Entrainment Studies. In: EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. Dixon, D. and K. Zammit (Ed.).

Mitchell, R.C. and R.T. Carson. 1986. "The Use of Contingent Valuation Data for Benefit/Cost Analysis of Water Pollution Control," Resources for the Future, Washington, D.C. September.

NEPMRI (New England Power Company and Marine Research Inc). 1981. Final Environmental Impact Report and Section 316(a) and 316(b) Demonstrations Made in Connection with the Proposed Conversion of Generating Unit No. 4 from Closed-Cycle Cooling to Once-Through Cooling.

NEPMRI (New England Power Company and Marine Research Inc). 1995. Brayton Point Station Annual Biological and Hydrological Report, January-December 1994.

New York State Department of Environmental Conservation. No Date. Unpublished tables of impingement data for steam electric stations in New York. Provided to U.S. EPA by Ed Radle, New York State Department of Environmental Conservation, January 2000.

Normandeau Associates Inc. 1984. Hudson River Ecological Study in the Area of Indian Point: 1983 Annual Report. Prepared for Consolidated Edison Company of New York, Inc., and New York Power Authority.

Normandeau Associates. 1994. Seabrook Environmental Studies 1993: A Characterization of Environmental Conditions in the Hampton-Seabrook Area During the Operation of Seabrook Station. Prepared for North Atlantic Energy Service Corporation.

Northeast Utilities Environmental Laboratory. 1999. Monitoring the Marine Environment of Long Island Sound at Millstone Nuclear Power Station 1998 Annual Report. 274 pp.

NRC (National Research Council). 1993. Managing Wastewater in Costal Urban Areas. National Academy Press, Washington, DC.

Potter, W.A. 1978. Assessment of the Effects of Impingement and Entrainment on the Fish Community of the New River, Virginia. Master's thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA. 70 pp.

Potter, W.A., E.D. Maruhnich, R.L. Shema and C.J. Cook. 1979a. Cardinal Plant Fish Impingement and Entrainment Studies. Prepared by Northern Environment Services Division for American Electric Power Service Corporation.

Potter, W.A., E.D. Maruhnich, R.L. Shema and C.J. Cook. 1979b. Kammer Plant Demonstration Document for P.L. 92-500 Section 316(b) Volume II: Kammer Plant Fish Impingement and Entrainment Studies. Prepared by NUS Corporation for the American Electric Power Service Corporation.

Potter, W.A., E.D. Maruhnich, R.L. Shema and C.J. Cook. 1979c. Kyger Creek Station Fish Impingement and Entrainment Studies. Prepared by Northern Environment Services Division for American Electric Power Service Corporation. October

Potter, W.A., E.D. Maruhnich, R.L. Shema and C.J. Cook. 1979d. Philip Sporn Plant Demonstration Document for P.L. 92-500 Section 316(b) Volume II, Appendix B: Philip Sporn Plant Fish Impingement and Entrainment Studies. Prepared by NUS Corporation for the American Electric Power Service Corporation.

PSE&G. 1999. Salem NPDES Permit Application, Appendix H.

Richkus, W.A. and R. McLean. 1998. Historical Overview of the Efficacy of Two Decades of Power Plant Fisheries Impact Assessment Activities in Chesapeake Bay. In: EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. Dixon, D. and K. Zammit (Ed.).

Ronafalvy, J.P., R.R. Cheesman, and W.M. Matejek. 1999. Circulating water traveling screen modifications to improve impinged fish survival and debris handling at Salem Generating Station. Presentation at Power Generation Impacts on Aquatic Resources Conference, Atlanta Georgia, April 12-15.

Ross, D.A. 1995. *Introduction to Oceanography.* Harper

Collins College Publishers. 496 pp.

Rowe, R.D., C.M. Lang, L.G. Chestnut, D.A. Latimer, D.A. Rae, S.M. Bernow, and D.E. White. 1995. The New York Electricity Externality Study, Volume 1. Empire State Electric Energy Research Corporation.

SAIC. 1993. Review of San Diego Gas & Electric Encina Power Plant 316(b) Demonstration. Draft. Prepared for U.S. EPA Region 9. 18 pp.

SAIC. 1994. Background Paper Number 3: Cooling Water Intake Technologies. Prepared for U.S. EPA Office of Wastewater Enforcement and Compliance, Permits Division by Science Applications International Corporation, Falls Church, VA.

SAIC. 1996. Background Paper Number 2: Cooling Water Use for Selected U.S. Industries. Prepared for U.S. EPA Office of Wastewater Enforcement and Compliance, Permits Division by Science Applications International Corporation, Falls Church, VA.

Sharma, R.K. and R.F. Freeman. 1977. Survey of Fish Impingement at Power Plants in the United States Volume I: The Great Lakes. ANL/ES-56 Volume I. Argonne National Laboratory, Argonne, IL, 218 pp.

Southern California Edison Company. 1987. Report on 1987 Data: Marine Environmental Analysis and Interpretation: San Onofre Nuclear Generating Station. 27 pp.

Spicer G., T. O'Shea, and G. Pichler. 1998. Entrainment Impingement and BTA Evaluation For an Intake Located on a Cooling Water Reservoir in the Southwest. In: EPRI Clean Water Act Section 316(b) Technical Workshop. EPRI Clean Water Act Section 316(b) Technical Workshop, September 22-24, Berkeley Springs, WV. Dixon, D. and K. Zammit (Ed.).

Spigarelli, S.A., A.J. Jensen, and M.M. Thommes. 1981. An Assessment of the Impacts of Water Intakes on Alewife, Rainbow Smelt, and Yellow Perch Populations in Lake Michigan. ANL/ES-109, EPA-905/3-81-001, Argonne National Laboratory and U.S. Environmental Protection Agency, March.

Stone & Webster Engineering Corporation. 1977. Supplemental Assessment in Support of the 316 Demonstration, Pilgrim Nuclear Power Station Units 1 and 2, Boston Edison Company.

Stone & Webster Engineering Corporation. 1980. 316(A) and (B) Demonstration Big Bend Station - Unit 4. Tampa Electric Company. Prepared for Tampa Electric Company.

Stupka, R.C. and R.K. Sharma. 1977. Survey of Fish Impingement at Power Plants in the United States Volume III: Estuaries and Coastal Waters. ANL/ES-56 Volume III. Argonne National Laboratory, Argonne, IL, 305 pp.

Taft, E.P. 1999. Fish protection technologies: A status report. Presentation at Power Generation Impacts on Aquatic Resources Conference, Atlanta Georgia, April 12-15.

Tennessee Division of Forestry, Fisheries, and Wildlife Development. 1976. Volume 5: Effects of the Gallatin Steam Plant Cooling Water Intake on the Fish Populations of Old Hickory Reservoir. Tennessee Division of Forestry, Fisheries, and Wildlife Development, Fisheries and Waterfowl Resources Branch, Norris, TN.

Tennessee Valley Authority. 1976. Volume 5: Effects of the Gallatin Steam Plant Cooling Water Intake on the Fish Populations of Old Hickory Reservoir. June 30.

Tennessee Valley Authority. 1977. 316 (a) and 316(b) Demonstration, Cumberland Steam Plant: Volume 5, Effects of the Cumberland Steam Plant Cooling Water Intake on the Fish Populations of Barkley Reservoir.

Tetra Tech Inc. 1978. Biological Effects of Once-Through Cooling Part I, Volume 2: The Marine Environment. Prepared by the Utility Water Act Group. Submitted to U.S. EPA. June.

Texas Instruments Inc. 1978. Biological Effects of Once-Through Cooling Part I, Volume 5: Great Lakes Basin and Connecting Water Bodies. Prepared for the Utility Water Act Group. Submitted to U.S. EPA.

Texas Instruments Inc. 1980. Hudson River Ecological Study in the Area of Indian Point: 1979 Annual Report. Prepared for Consolidated Edison Company on New York, Inc.

Thurber, N.J. and D.J. Jude. 1985. Impingement Losses at the D. C. Cook Nuclear Power Plant During 1975-1982 with a Discussion of Factors Responsible and Possible Impact on Local Populations. Special Report No. 115 of the Great Lakes Research Division, Great Lakes and Marine Waters Center, University of Michigan.

U.S. DOI. 1997. U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. *1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.* U.S. Government Printing Office, Washington, DC.

U.S. EPA. 1976. Development Document for Best Technology Available for the Location, Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact. Office of Water and Hazardous Materials, Effluent Guidelines Division, U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1982. Determination Regarding Modification of NPDES Permit No. MA0003654 for Brayton Point Station, Somerset, Massachusetts. 107 pp.

Van Winkle, W., L.W. Barnthouse, B.L. Kirk and D.S. Vaughan. 1980. Evaluation of Impingement Losses of White Perch at the Indian Point Nuclear Station and Other Hudson River Power Plants. Prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission. Environmental Sciences Division Publication No. 1480. NUREG/CR-1100. 133 pp.

Whitehead, P.J.P. 1985. FAO Species Catalogue, Volume 7. Clupeoid Fishes of the World. FAO Fish. Synop. 7(125), Pt. 1, 303 pp.