Appendix C2: Scaling of Habitat Restoration

Introduction

This appendix presents the data and methods used to develop (1) estimates of fish production in tidal wetland and submerged aquatic vegetation (SAV) habitats for species dependent on these habitats that are lost to impingement and entrainment (I&E) at the Brayton Point Station and (2) estimates of the acres of each habitat type that would need to be restored to offset I&E losses of these species.

Appendix Contents

C2-1 Identify Habitat Restoration Actions for Species with I&E Losses

EPA categorized and prioritized habitat restoration alternatives for species lost to I&E at Brayton Point in collaboration with local experts from several Federal, State, and local organizations at a meeting on September 10, 2001 (Table C2-1) and through follow-up discussions that were held with numerous additional organizations (Table C2-2). Attendees discussed habitat needs and restoration options for each species with significant I&E losses at the facility. They then ranked these restoration options for each species by determining what single option would most benefit that species. Species for which tidal wetland or SAV restoration was selected are shown in Table C2-3. The scale of restoration for these habitats is used in Chapter C6 to estimate the non-use value of I&E losses at the Brayton Point facility.

Table C2-1: Attendees at the Meeting on Habitat Prioritization for Species Impinged and Entrained at Brayton Point September 10, 2001, in Fall River, Massachusetts

Attendee	Organization
Anthony Chatwin	Conservation Law Foundation
Robert Lawton	Massachusetts Division of Marine Fisheries
Andrea Langhauser	Massachusetts Watershed Initiative — Ten Mile and Mount Hope Bay Watersheds
Kathi Rodrigues	National Marine Fisheries Service — Restoration Center
Chris Powell	Rhode Island Department of Environmental Management — Fish and Wildlife Division
Tom Ardito	Rhode Island Department of Environmental Management — Narragansett Bay Estuary Program
Andy Lipsky	Save the Bay
John Torgan	Save the Bay
Phil Colarusso	U.S. EPA Region I
John Nagle	U.S. EPA Region I

Table C2-2: Other Local Agencies and Organizations Contacted for Information

Organization
Applied Sciences Associates
Atlantic States Marine Fisheries Council
Connecticut College
Duxbury Conservation Agency
Fall River Conservation Commission
Jones River Watershed Association
Massachusetts Office of Coastal Zone Management
Massachusetts Department of Environmental Protection
Massachusetts Department of Fisheries, Wildlife, and Law Enforcement — Division of Marine Fisheries
Massachusetts Institute of Technology Sea Grant Program: Center for Coastal Resources
Massachusetts Watershed Initiative
Metropolitan Area Planning Commission
Narragansett Estuarine Research Reserve
National Estuary Program — Massachusetts Bays program
National Estuary Program — Narragansett Bay Estuary Program
New Jersey Department of Environmental Protection
New Jersey Marine Sciences Consortium
NOAA — National Marine Fisheries Service
NOAA — National Marine Fisheries Service — Restoration Center (Gloucester, MA)
NOAA — National Marine Fisheries Service — Restoration Center (Providence, RI)
NOAA — National Marine Fisheries Service (NC)
Rhode Island Coastal Resource Management Council
Rhode Island Department of Environmental Management
Rhode Island Department of Environmental Management — Dept. of Planning and Development, Land Acquisition Program
Rhode Island Department of Environmental Management — Division of Fish and Wildlife
Rhode Island Department of Environmental Management — Marine Fisheries Section
Roger Williams University
Rutgers University
Save The Bay (RI)
Somerset Conservation Commission
University of California — Santa Cruz: Department of Ecology and Evolutionary Biology
University of New Hampshire
University of Rhode Island
USEPA — Region 1
USEPA Environmental Effects Research Laboratory — Atlantic Ecology Division/ORD
US Fish and Wildlife Service
USGS
Wetlands Restoration Program, (Mass Exec. Office of Env. Affairs)
Woods Hole Oceanographic Institution

Table C2-3: Experts Selection of Species for Tidal Wetland or SAV Restoration to Offset I&E Losses at Brayton Point

Species	Selected Restoration Alternative
Threespine stickleback	SAV restoration
Weakfish	SAV restoration
Scup	SAV restoration
Winter flounder	Tidal wetlands restoration
Atlantic silverside	Tidal wetlands restoration
Striped killifish	Tidal wetlands restoration

C2-2 Expected Increase in Fish Production from Restoration of Tidal Wetland and SAV Habitats

Unfortunately, available quantitative data are not sufficient to estimate reliably the increase in fish production that is expected to result from tidal wetland or SAV restoration in the region around Brayton Point. Therefore, in this analysis EPA relied on quantitative information on fish species abundance in the habitats to be restored as a proxy for production. The relationship between the measured abundance of a species in a given habitat and the increase in that species' production that would result from restoring additional habitat is complex and unique for each species. In some cases the use of abundance data may underestimate the true production that would be gained through habitat restoration, and in other cases it may overestimate the true production. Nevertheless, this assumption was necessary given the limited amount of quantitative data on fish species habitat production that is currently available.

This analysis assumes that estimates of age-1 equivalent abundance in wetlands provide reasonable estimates of the age-1 equivalent production that would be realized, on a per-acre basis, if additional acres of tidal wetland and SAV habitat were restored. This assumption implies that, when restored acres have reached their full potential, they will produce additional age-1 fish in the same mix of species and at the quantities observed in sampling of existing undisturbed habitats.

C2-2.1 Calculating Age 1 Fish Abundance in SAV to Estimate Increased Production from SAV Restoration

SAV provides forage and refuge for many fish species, increases sediment stability, and dampens the energy of waves and currents affecting nearby shorelines (Fonseca, 1992). SAV restoration is most effective where water quality is adequate and SAV coverage once existed.

No studies were available that provided direct estimates of increased fish production following SAV restoration for the SAV-dependent species impinged and entrained at Brayton Point. Therefore, EPA used abundance estimates to estimate increases in production following restoration. Abundance estimates are often the best available estimates of fish habitat productivity. The sampling efforts that provide abundance estimates in SAV habitat and that were selected for restoration scaling are described below.

a. Species abundance in Buzzards Bay SAV

Wyda et al. (2002) provide abundance estimates as fish per 100 m^2 of SAV for species caught in otter trawls in July and August 1996 at 24 sites within 13 Buzzards Bay estuaries, near Nantucket, Massachusetts, and at 28 sites within 6 Chesapeake Bay estuaries. These locations were selected based on information that eelgrass was present or had existed at the location.

The sampling at each location consisted of six, 2-minute sampling runs using a 4.8 m semi-balloon otter trawl with a 3 mm mesh cod end liner that was towed at 5-6 km/hour. Late summer sampling was selected because eelgrass abundance is greatest then, and previous research had shown that late-summer fish assemblages are stable.

Forty-three fish species were caught in Buzzards Bay and 60 in Chesapeake Bay. Abundance estimates per 100 m^2 of SAV were reported for all fish species, and abundance estimates for specific SAV density categories were reported for species caught in more than 10 percent of the total number of trawls (15 species). EPA used only results from Buzzards Bay sampling because of the Bay's proximity to the Brayton Point facility. These SAV density-based results are presented in Table C2-4 for species impinged and entrained at Brayton Point and identified as benefitting most from restoration of SAV.

Table C2-4: Average Abundance in Buzzards Bay SAV (eelgrass) Habitats for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from SAV Restoration

Common Name	Species Abundance (# fish per 100 m^2)[a]	
	Low Density SAV Habitats	High Density SAV Habitats
Threespine stickleback	0.22	0.13
Weakfish[b]	no obs.	no obs.
Scup	0.32	1.03

[a] High density habitats are eelgrass areas with shoot densities > 100 per m^2 and shoot biomass (wet) > 100 g/m^2. Low density habitats do not meet these criteria.
[b] Weakfish were not among the species caught in more than 10 percent of the Buzzards Bay trawls.

Source: Wyda et al. (2002).

b. Species abundance in Rhode Island Coastal Salt Pond SAV

Hughes et al. (2000) conducted trawl samples in the SAV habitats of four Rhode Island coastal estuarine salt ponds and in four Connecticut estuaries during July 1999. As in Wyda et al. (2002), the sampling at each location involved six, 2-minute sampling runs using a 4.8 m semi-balloon otter trawl with a 3 mm mesh cod end liner towed at 5-6 km/hour.

The report does not provide abundance estimates by species. However, a principal investigator provided EPA with abundance estimates expressed as the number of fish per 100 m^2 of SAV for the locations sampled in Rhode Island (Point Judith Pond, Ninigret Pond, Green Hill Pond, and Quonochontaug Pond; personal communication, J. Hughes, NOAA Marine Biological Laboratory, 2001). Average abundance estimates per 100 m^2 of SAV were calculated for each species and allocated to the same SAV habitat categories that were designated in Wyda et al. (2002) using shoot density and wet weight of shoots from Hughes et al. (2000). The sampling results for species impinged and entrained at Brayton Point and identified as benefitting most from SAV restoration are presented in Table C2-5.

Table C2-5: Average Abundance from Rhode Island SAV Sites for Brayton Point Species that Would Benefit Most from SAV Restoration

Species	Species Abundance (# fish per 100 m^2 of SAV habitat)[a]	
	Low Density SAV Habitats	High Density SAV Habitats
Threespine stickleback	no obs.	19.67
Weakfish	no obs.	no obs.
Scup	0.17	0.69

[a] High density habitats are defined as areas with eelgrass shoot densities > 100 per m^2 and shoot biomass (wet) > 100 g/m^2. Low density habitats do not meet these criteria.

Source: personal communication, J. Hughes, NOAA, Marine Biological Laboratory, 2001.

c. Species abundance in Nauset Marsh (Massachusetts) Estuarine Complex SAV

Heck et al. (1989) provide capture totals for day and night trawl samples taken between August 1985 and October 1986 in the Nauset Marsh Estuarine Complex in Orleans/Eastham, Massachusetts, including two eelgrass beds: Fort Hill and Nauset Harbor. As in the other SAV sampling efforts, an otter trawl was used for the sampling, but with slightly larger mesh size openings in the cod end liner (6.3 mm versus 3.0 mm) than in Hughes et al. (2000) or Wyda et al. (2002).

With the reported information on the average speed, duration, and number of trawls used in each sampling period and an estimate of the width of the SAV habitat covered by the trawl from one of the study authors (personal communication, M. Fahay, NOAA, 2001), EPA calculated abundance estimates per 100 m^2 of SAV habitat.

Heck et al. (1989) also report that the dry weight of the SAV shoots is over 180 g/m^2 at both the Fort Hill and Nauset Harbor eelgrass habitat sites. Therefore, these locations would fall into the high SAV habitat category used in Wyda et al. (2002) and Hughes et al. (2000) because the dry weight exceeds the wet weight criterion of 100 g/m^2 used in those studies.

Finally, Heck et al. (1989) provide separate monthly capture results from their trawls. The maximum monthly capture results for each species was used for the abundance estimates from this sampling. Because these maximum values generally occur in the late summer months, sampling time is consistent with the results from Wyda et al. (2002) and Hughes et al. (2000).

The abundance values estimated from the sampling of the Fort Hill and Nauset Harbor SAV habitats for species impinged and entrained at Brayton Point and identified as benefitting most from SAV restoration are presented in Table C2-6.

Table C2-6: Average Abundance in Nauset Marsh Estuarine Complex SAV for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from SAV Restoration

Species	Species Abundance (# fish per 100 m^2)[a]	
	Fort Hill — High Density SAV	Nauset Harbor — High Density SAV
Threespine stickleback	5.92	47.08
Weakfish	No obs.	No obs.
Scup	No obs.	0.08

[a] High density habitats are defined as areas with eelgrass shoot densities > 100 per m^2 and shoot biomass (wet) > 100 g/m^2.

Source: Heck et al., 1989.

C2-2.1.1 Adjusting SAV sampling results to estimate annual average increase in production of age 1 fish

EPA adjusted sampling-based abundance estimates to account for:

- sampling efficiency
- capture of life stages other than age 1
- differences in the measured abundances in natural SAV habitat versus expected productivity in restored SAV habitat.

The basis and magnitude of the adjustments are discussed in the following sections.

a. Adjusting for sampling efficiency

Fish sampling techniques are unlikely to capture or record all of the targeted fish(e.g., fish of a certain lifestage) present in a sampled area because some fish avoid the sampling gear and some are captured but not collected and counted. An estimated range for the sampling efficiency for 4.9 meter otter trawls of 6 percent to 26 percent (PSE&G, 1999 — see Table 5 in Appendix G-4). EPA incorporated the endpoints from this range to provide a similar range of abundance estimates.

b. Adjusting sample abundance estimates to age 1 life stages

All sampled life stages were converted to age 1 equivalents for comparison to I&E losses, which were expressed as age 1 equivalents. The average life stage of the fish caught in Buzzards Bay (Wyda et al., 2002) and the Rhode Island coastal salt pond (Hughes et al., 2000) was juveniles (i.e., life stage younger than age 1) (personal communication, J. Hughes, NOAA Marine Biological Laboratory, 2001). Since the same sampling technique and gear were used in Heck et al. (1989), EPA assumed juveniles to be the average life stage captured in this study as well.

The abundance estimates from the studies were multiplied by the survival rates from juveniles to age 1 for each species to provide an age 1 equivalent abundance. The juvenile to age-1 survival fractions and data sources used by EPA are presented in Appendix C1 of this report and in Table C2-7.

Table C2-7: Life Stage Adjustment Factors for Species Present at Brayton Point — SAV Restoration

Species	Estimated Survival Fraction for Juveniles to Age 1
Threespine stickleback	0.3077
Weakfish	0.0654
Scup	0.0671

c. Adjusting sampled abundance for differences between restored and undisturbed habitats

No reviewed studies suggested that restored SAV habitat would produce fish at a level different from undisturbed SAV habitat. In addition, limited anecdotal evidence suggests some restored SAV habitats may begin recruiting and producing fish very quickly (personal communication, A. Lipsky, Save the Bay, 2001). Based on this information, EPA made no adjustment for differences between restored and undisturbed SAV habitats to account for the final levels of fish production or potential lags in realizing these levels following restoration of SAV habitat.

C2-2.1.2 Final estimates of annual average age 1 fish production from SAV restoration

EPA calculated age 1 fish production in restored SAV by multiplying the abundance estimates from Wyda et al. (2002), Hughes et al. (2000), and Heck et al. (1989) by the survival fractions presented in Table C2-7 and then averaging across sampling locations. Table C2-8 presents the final estimates of the increase in age 1 production for two of the three Brayton Point species that benefit most from SAV restoration (weakfish were not sampled in any of the studies providing abundance estimates). This averaged value was then adjusted by the alternative estimates of the sampling gear efficiency of 6 percent and 26 percent and then results were expressed on a per-acre basis (i.e., multiplied by 40.47 based on 4,047 m^2 per acre). The resulting range of abundance estimates are presented in Table C2-9.

Table C2-8: Final Estimates of the Increase in Production of Age 1 Fish for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from SAV Restoration

Species	Source of Initial Species Abundance Estimate	Species Abundance Estimate per 100 m^2 of SAV	Life Stage Adjustment Factor	Restored Habitat Service Flow Adjustment Factor	Expected Increase in Production of Age 1 Fish per 100 m^2 of Restored SAV
Threespine stickleback	Heck et al. (1989) — Fort Hill	5.92	0.3077	1.0	1.82
	Heck et al. (1989) — Nauset Harbor	47.08	0.3077	1.0	14.49
	Hughes et al. (2000) — RI coastal ponds (high SAV)	19.67	0.3077	1.0	6.05
	Wyda et al. (2002) — Buzzards Bay (low SAV)	0.22	0.3077	1.0	0.07
	Wyda et al. (2002) — Buzzards Bay (high SAV)	0.13	0.3077	1.0	0.04
	Species average				**4.49**
Weakfish	Unknown				
Scup	Heck et al. (1989) — Nauset Harbor	0.08	0.0671	1.0	0.01
	Hughes et al. (2000) — RI coastal ponds (low SAV)	0.17	0.0671	1.0	0.01
	Hughes et al. (2000) — RI coastal ponds (high SAV)	0.69	0.0671	1.0	0.05
	Wyda et al. (2002) — Buzzards Bay (low SAV)	0.32	0.0671	1.0	0.02
	Wyda et al. (2002) — Buzzards Bay (high SAV)	1.03	0.0671	1.0	0.07
	Species average				**0.03**

Table C2-9: Life Stage Adjustment Factors for Species Present at Brayton Point — SAV Restoration			
Species	**Expected Increase in Production of Age 1 Fish per 100 m² of Restored SAV**	**Assumed Sampling Gear Efficiency**	**Expected Increase in Production of Age 1 Fish per Acre of Restored SAV (rounded to nearest unit)**
Threespine stickleback	4.49	6%	3,031
		26%	699
Weakfish	No data		
Scup	0.03	6%	21
		26%	5

C2-2.2 Estimates of Increased Age 1 Fish Production from Tidal Wetland Restoration

Table C2-10 identifies the I&E losses for fish species at Brayton Point that would benefit most from tidal wetland restoration, along with their estimated annual average age-1 equivalent I&E losses.

Table C2-10: Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration	
Species	**Annual Average I&E Loss of Age 1 Equivalents**
Winter flounder	512,081
Atlantic silverside	39,815
Striped killifish	796
Total	552,692

EPA used results from tidal wetland sampling efforts in Rhode Island to calculate the potential increased fish production from restored tidal wetland habitat in Mount Hope Bay where Brayton Point is located. In selecting data for consideration, EPA decided to not to incorporate data from recently restored sites because in most cases the data were available from only 1 or 2 years following the restoration action and therefore may not be indicative of the long-term average.

a. Species abundance at Sachuest Point Tidal Wetland, Middletown, Rhode Island

Roman et al. (2002) sampled the fish populations in a 6.3 ha tidal wetland at Sachuest Point in Middletown, Rhode Island. The sampling was conducted during August, September, and October of 1997, 1998, and 1999 using a 1 m^2 throw trap in the creeks and pools of each area during low tide after the wetland surface had drained. Additional sampling was conducted monthly from June through October in 1998 and 1999 using 6 m^2 bottomless lift nets to sample the flooded wetland surface. Table C2-11 presents results as abundance per square meter.

Table C2-11: Abundance Estimates from the Unrestricted Tidal Wetlands at Sachuest for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Sampling Technique	Fish Density Estimates in Unrestricted Tidal Wetlands (fish per m^2)		
		1997	1998	1999
Winter flounder	Throw trap	No obs.	No obs.	No obs.
	Lift net	No sampling	No obs.	No obs.
Atlantic silverside	Throw trap	1.23	0.20	0.07
	Lift net	No sampling	No obs.	No obs.
Striped killifish	Throw trap	0.70	0.17	0.55
	Lift net	No sampling	0.01	0.01

Source: Roman et al. (2002).

b. Galilee Marsh, Narragansett Rhode, Island

Raposa (2002) sampled the fish populations in the Galilee tidal wetland monthly from June through September of 1997, 1998, and 1999 using 1 m^2 throw trap in the creeks and pools in the tidal wetland parcels during low tide after the wetland surface had drained. Raposa presents the sampling results as number of fish per square meter. As with the results from Roman et al. (2002), EPA did not use the results from a recently restored portion of the wetland to avoid a downward bias in the species density results. The results from this sampling effort are presented in Table C2-12 for the species impinged and entrained at Brayton Point and identified as benefitting most from tidal wetlands restoration.

Table C2-12: Abundance Estimates from the Unrestricted Tidal Wetlands at Galilee for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Sampling Technique	Fish Density Estimates in Unrestricted Tidal Wetlands (fish per m^2)		
		1997	1998	1999
Winter flounder	Throw trap	No obs.	No obs.	No obs.
Atlantic silverside	Throw trap	4.78	1.73	14.38
Striped killifish	Throw trap	4.35	3.50	12.40

Source: Raposa, 2002.

c. Coggeshall Marsh, Prudence Island, Rhode Island

Discussions with Kenny Raposa of the Narragansett Estuarine Research Reserve (NERR) revealed that additional fish abundance estimates from tidal wetland sampling were available for the Coggeshall Marsh located on Prudence Island in the NERR. These abundance estimates were based on sampling conducted in July and September 2000. The sampling of the Coggeshall tidal wetland was conducted using 1 m^2 throw traps in the tidal creeks and pools of the wetland during ebb tide after the wetland surface had drained (personal communication, K. Raposa, Narragansett Estuarine Research Reserve, 2001). The sampling results from this effort are presented in Table C2-13 for the species impinged and entrained at Brayton Point and identified as benefitting most from tidal wetlands restoration.

Table C2-13: Abundance Estimates from the Unrestricted Tidal Wetlands at Coggeshall for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Sampling Technique	Fish Density Estimates in Tidal Wetlands (fish per m^2)	
		July 2000	September 2000
Winter flounder	Throw trap	0.10	0.10
Atlantic silverside	Throw trap	0.17	0.07
Striped killifish	Throw trap	2.40	0.53

d. Winter flounder data from Rhode Island juvenile finfish survey at the Chepiwanoxet and Wickford sample locations

The Rhode Island juvenile finfish survey samples 18 locations once a month from June through October using a beach seine that is approximately 60 m (200 ft) long and 3 m (10 ft) wide/deep. The sampled sites vary from cobble reef to sandy substrate. Winter flounder prefer shallow water habitats with sandy substrate, and such substrate conditions can be restored in large coastal ponds or pools. Therefore, EPA obtained winter flounder abundance estimates from this survey (personal communication, C. Powell, Rhode Island Department of Environmental Management, 2001). The two sample locations with the highest average winter flounder abundance estimates for 1990 through 2000 were in coastal ponds with sandy bottoms. The average abundance estimates from these sites, Chepiwanoxet and Wickford, are presented in Table C2-14 for samples taken from 1990 through 2000.

Table C2-14: Average Winter Flounder Abundance, 1990-2000, at the Sites with the Highest Results from the Rhode Island Juvenile Finfish Survey

Species	Sampling Technique	Fish Density Estimates in Sandy Nearshore Substrate (fish per m^2)	
		Chepiwanoxet 1990-2000	Wickford 1990-2000
Winter flounder	Beach seine	0.09	0.20

e. Winter flounder data from Rhode Island coastal pond survey at Narrow River, Winnapaug Pond, and Point Judith Pond

In addition to its juvenile finfish survey, Rhode Island conducts a survey of fish in its coastal ponds. The habitat characteristics in these locations are similar to those that can be restored through tidal wetland restoration. A Rhode Island coastal pond survey has been conducted since 1998 at the same 16 sites using an approximately 40 m (130 ft) long seine that is set offshore by boat and then drawn in from shore by hand. For each site, the average of the three highest winter flounder capture results for 1998-2001, adjusted for the average area covered by each seine set, is presented in Table C2-15 (personal communication, J. Temple, Rhode Island Division of Fish and Wildlife, 2002).

Table C2-15: Average Winter Flounder Abundance for 1998-2001 at the Sites with the Highest Results from the Rhode Island Coastal Pond Survey

Species	Sampling Technique	Average Winter Flounder Density Estimates in Sandy Nearshore Substrate (fish per m^2)		
		Narrow River	Winnapaug Pond	Point Judith Pond
Winter flounder	Beach seine	0.32	0.21	0.21

C2-2.2.1 Adjusting tidal wetland sampling results to estimate annual average increase in production of age 1 fish

The sampling abundance results presented in Section C2-2.2.1 were adjusted to account for the following:

- sampling efficiency
- conversion to the age 1 life stage
- differences in production between restored and undisturbed tidal wetlands
- the impact of sampling timing and location.

a. Sampling efficiency

As previously described, sampling efficiency adjustments are made to account for the fact that sampling techniques do not capture all fish that are present. Jordan et al. (1997) estimated that 1 m^2 throw traps have a sampling efficiency of 63 percent. Therefore, EPA applied an adjustment factor of 1.6 (i.e., 1.0/0.63) to tidal wetland abundance data that were collected with 1 m^2 throw traps.

Species-specific estimates of sampling efficiencies of bottomless lift nets are provided in Rozas (1992) as 93 percent for striped mullet (*Mugil cephalus*), 81 percent for gulf killifish (*Fundulus grandis*), and 58 percent for sheepshead minnow (*Cyprinodon variegatus*). The average of these three sampling efficiencies is 77 percent (adjustment factor of 1.3, or 1.0/0.77) and is assumed to be applicable to species lost to I&E at Brayton Point.

Lastly, although specific studies of the sample efficiency of a beach seine net were not identified, an estimated range of 50 percent to 75 percent was provided by the staff involved with the Rhode Island coastal pond survey (personal communication, J. Temple, Rhode Island Division of Fish and Wildlife, 2002). Using the lower end of this range as a cost reducing assumption, EPA applied a sample efficiency adjustment factor of 2.0 (i.e., 1.0/0.5) for the abundance estimates for both the Rhode Island juvenile finfish survey and the Rhode Island coastal pond survey.

b. Conversion to age 1 life stage

The sampling techniques described in Section C2-2.2.1 are intended to capture juvenile fish (personal communication, K. Raposa, Narragansett Estuarine Research Reserve, 2001). That juvenile fish were the dominant age class taken was confirmed by the researchers involved in these efforts (personal communication, K. Raposa, Narragansett Estuarine Research Reserve, 2001; personal communication, C. Powell, Rhode Island Department of Environmental Management, 2001; personal communication, J. Temple, Rhode Island Division of Fish and Wildlife, 2001). As a result, the sampling results presented in Section C2-2.2.1 required adjustment to account for expected mortality between the juvenile and age 1 life stages. The juvenile to age-1 survival fractions and data sources used by EPA are presented in Appendix C1 of this report and in Table C2-16.

Table C2-16: Life Stage Adjustment Factors for Species Present at Brayton Point — SAV Restoration

Species	Estimated Survival Fraction for Juveniles to Age 1
Winter flounder	0.1697
Atlantic silverside	0.1347
Striped killifish	0.5714

c. Adjusting for differences between restored and undisturbed habitats

Restoring full tidal flows rapidly eliminates differences in fish populations between unrestricted and restored sites (Roman et al., 2002), resulting in very similar species composition and density (Dionne et al., 1999; Fell et al., 2000; Warren et al., 2002). However, there can be a lag before this occurs following restoration (Raposa, 2002). Given uncertainty over the length of this lag, and the rate at which increased productivity in a restored tidal wetland approaches its long-term average rate, EPA incorporated an adjustment factor of 1.0 to signify that no quantitative adjustment was made for any potential lag.

d. Adjusting sampled abundance for timing and location of sampling

At high tide, fish have access to the full range of acreage in a tidal wetland, including the flooded vegetation, ponds, and creeks that discharge into or drain the tidal wetland. In contrast, at low tide, fish are restricted to tidal pools and subtidal creeks. To account for these differences, EPA incorporated a simplifying assumption that the juvenile fish using the tidal wetland that are being captured in the sampling efforts would be concentrated in tidal pools and subtidal creeks in sampling conducted at low tide. To account for this presumed concentration, EPA divided abundance estimates based on samples taken at low tide by the inverse of the proportion of subtidal habitat to total wetland habitat at a site. In contrast, no adjustment was applied to abundance estimates based on samples such as those from lift nets or seines, taken at high tide or in open water offshore of a tidal wetland. The site-specific adjustment factors to account for this assumption are presented in Table C2-17 are based on information on the subtidal proportion of each tidal wetland sampled at low tide (personal communication, K. Raposa, Narragansett Estuarine Research Reserve, 2001).

Table C2-17: Adjustment Factors for Tidal Wetland Sampling Conducted at Low Tide

Tidal Wetland	Ratio of Open Water (creeks, pools) to Total Habitat in the Wetland	Adjustment Factor
Sachuest Marsh	0.055	18.2
Galilee Marsh	0.084	11.9
Coggeshall Marsh	0.052	19.2

C2-2.2.2 Final estimates of annual average age 1 fish production from tidal wetland restoration

Based on the average value across all locations, Table C2-18 presents the final estimates of annual increased production of age 1 fish resulting from tidal wetland restoration for species impinged and entrained at Brayton Point and identified as benefitting most from tidal wetland restoration.

The average abundance estimates for the tidal wetland species presented in Table C2-18 are presented below in Table C2-19 in terms of their equivalent per acre values, following multiplication by 4,047 to account for the number of square meters per acre.

Table C2-18: Final Estimates of the Annual Increase in Production of Age 1 Equivalent Fish per Square Meter of Restored Tidal Wetland for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Source of Initial Species Density Estimate	Sampling Location and Date[a]	Reported/Calculated Species Density Estimate per m^2 of Tidal Wetland	Sampling Efficiency Adjustment Factor	Life Stage Adjustment Factor	Restored Habitat Service Flow Adjustment Factor	Sampling Time and Location Adjustment Factor	Increased Production of Age 1 Fish per m^2 of Restored Tidal Wetland[bc]
Winter flounder	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall - July 2000	0.10	1.6	0.1697	1	19.23	0.00
	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall — Sept. 2000	0.10	1.6	0.1697	1	19.23	0.00
	C Powell pers comm 2001	Chepiwanoxet average 1990-2000 (seine)	0.09	2.0	0.1697	1	1.00	0.03
	C Powell pers comm 2001	Wickford average 1990-2000 (seine)	0.20	2.0	0.1697	1	1.00	0.07
	J. Temple pers comm 2002	Narrow River average 1998-2001 (seine)	0.32	2.0	0.1697	1	1.00	0.11
	J. Temple pers comm 2002	Winnapaug Pond average 1998-2001 (seine)	0.21	2.0	0.1697	1	1.00	0.07
	J. Temple pers comm 2002	Point Judith Pond average 1998-2001 (seine)	0.21	2.0	0.1697	1	1.00	0.07
	Species average							**0.05**
Atlantic silverside	Roman et al., 2002	Sachuest Point — 1997	1.23	1.6	0.1347	1	18.18	0.01
	Roman et al., 2002	Sachuest Point — 1998	0.20	1.6	0.1347	1	18.18	0.00
	Roman et al., 2002	Sachuest Point — 1999	0.07	1.6	0.1347	1	18.18	0.00
	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall - July 2000	0.17	1.6	0.1347	1	19.23	0.00
	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall — Sept. 2000	0.07	1.6	0.1347	1	19.23	0.00
Atlantic silverside	Raposa, 2002	Galilee Marsh — 1997	4.78	1.6	0.1347	1	11.90	0.09
	Raposa, 2002	Galilee Marsh — 1998	1.73	1.6	0.1347	1	11.90	0.03
	Raposa, 2002	Galilee Marsh — 1999	14.38	1.6	0.1347	1	11.90	0.26
	Species average							**0.05**

Table C2-18: Final Estimates of the Annual Increase in Production of Age 1 Equivalent Fish per Square Meter of Restored Tidal Wetland for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Source of Initial Species Density Estimate	Sampling Location and Date[a]	Reported/Calculated Species Density Estimate per m^2 of Tidal Wetland	Sampling Efficiency Adjustment Factor	Life Stage Adjustment Factor	Restored Habitat Service Flow Adjustment Factor	Sampling Time and Location Adjustment Factor	Increased Production of Age 1 Fish per m^2 of Restored Tidal Wetland[bc]
Striped killifish	Roman et al., 2002	Sachuest Point — 1997	0.70	1.6	0.5714	1	18.18	0.04
	Roman et al., 2002	Sachuest Point — 1998	0.17	1.6	0.5714	1	18.18	0.01
	Roman et al., 2002	Sachuest Point — 1999	0.55	1.6	0.5714	1	18.18	0.03
	Roman et al., 2002	Sachuest Point — 1998 (lift net)	0.01	1.3	0.5714	1	1.00	0.01
	Roman et al., 2002	Sachuest Point — 1999 (lift net)	0.01	1.3	0.5714	1	1.00	0.01
	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall — July 2000	2.40	1.6	0.5714	1	19.23	0.11
	Raposa pers comm 2001	NERR — Prudence Isl. Coggeshall — Sept. 2000	0.53	1.6	0.5714	1	19.23	0.03
	Raposa, 2002	Galilee Marsh — 1997	4.35	1.6	0.5714	1	11.90	0.33
Striped killifish	Raposa, 2002	Galilee Marsh — 1998	3.50	1.6	0.5714	1	11.90	0.27
	Raposa, 2002	Galilee Marsh — 1999	12.40	1.6	0.5714	1	11.90	0.95
	Species average							**0.18**

[a] Sampling results are based on collections using 1 m^2 throw traps unless otherwise noted.
[b] Calculated by multiplying the initial species density estimate by the sampling efficiency, life stage, and restored habitat service flow adjustment factors and dividing by the sampling time and location adjustment factor. Values are rounded for presentation purposes only
[c] Values of 0.00 presented in the table have an abundance of less than 0.005 fish per m^2 so do not appear in the rounding of results for purposes of presentation.

Table C2-19: Estimates of the Annual Increase in Production of Age 1 Equivalent Fish per Acre of Restored Tidal Wetland for Fish Species Impinged or Entrained at Brayton Point that Would Benefit Most from Tidal Wetland Restoration

Species	Expected Increase in Production of Age 1 Fish per Acre of Restored Tidal Wetland
Winter flounder	205
Atlantic silverside	202
Striped killifish	721

C2-3 Scaling of I&E Losses with Habitat Production Abundance Estimates

Table C2-20 presents the estimates of the average annual age-1 equivalent I&E losses of fish at Brayton Point by species.

Table C2-20: Mean Annual Age 1 Equivalent I&E Losses of Fishes at Brayton Point, 1974-1983 ACO

Species	I&E Total
Seaboard goby	1,513,836
Bay anchovy	1,233,697
Winter flounder	512,081
American sand lance	453,236
Rainbow smelt	50,872
Atlantic silverside	39,815
Hogchoker	37,169
Tautog	30,196
Atlantic menhaden	10,594
Windowpane	7,725
Other forage species	7,195
Alewife	3,580
Threespine stickleback	2,260
Striped killifish	796
Weakfish	557
Scup	509
Silver hake	438
Blueback herring	342
Butterfish	271
White perch	2
Total age 1 equivalent losses	**3,905,171**

The following subsections calculate the required scale of implementation for SAV and tidal wetlands. To determine the appropriate scale of restoration, the species-specific quantified I&E losses are first divided by the corresponding estimates of increased fish production in the relevant habitats. This produces a range of restoration acreage estimates for a given set of assumptions. Second, following a commonly used restoration scaling selection rule, the estimates for the species requiring the maximum amount of restoration, for a given set of assumptions (e.g., sampling gear efficiency) is selected as the estimate of required restoration. This decision rule is used to ensure that the losses for all other species will also be offset under the selected scale of action.

C2-3.1 Submerged Aquatic Vegetation Scaling

The information used to scale SAV restoration is presented in Table C2-21 incorporating the loss estimates from Table C2-20 and the SAV production estimates of age-1 equivalent fish per acre of restored SAV from Table C2-9.

Table C2-21: Scaling of SAV Restoration Species Impinged or Entrained at Brayton Point

Species	Annual Average I&E Loss of Age 1 Equivalents	Estimated increase in Production of Age-1 Equivalent Fish per Acre of Restored SAV (rounded to nearest fish)		Estimated Acres of Restored SAV Required to Offset Annual Average Loss of Age-1 Equivalent Fish (rounded to nearest acre)	
		Low	High	Low	High
Scup	509	5	21	24	102
Threespine stickleback	2,260	699	3,031	1	3
Weakfish	557	No data		n/a	
Acres of SAV restoration required to offset I&E losses for these species				**24**	**102**

C2-3.2 Tidal Wetlands Scaling

The information used to scale tidal wetland restoration is presented in Table C2-22 incorporating the loss estimates from Table C2-20 and the tidal wetland production estimates of age-1 equivalent fish per acre of restored tidal wetland from Table C2-19.

Table C2-22: Scaling of Tidal Wetland Restoration Species Impinged or Entrained at Brayton Point

Species	Annual Average I&E Loss of Age 1 Equivalents	Expected Increase in Production of Age-1 Fish per Acre of Restored Tidal Wetland (rounded to nearest fish)	Estimated Acres of Restored Tidal Wetlands Required to Offset Annual Average Loss of Age-1 Equivalent Fish (rounded to nearest acre)
Winter flounder	512,081	205	2,498
Atlantic silverside	39,815	202	197
Striped killifish	796	721	1
Acres of tidal wetland restoration required to offset I&E losses for these species			**2,498**