BEFORE THE ENVIRONMENTAL APPEALS BOARD
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

In re: Dominion Energy Brayton Point, LLC (formerly USGen. New England, Inc. Brayton Point Station)	)	**NPDES Appeal No. 07-01**
NPDES Permit No. MA 0003654	)	

EXHIBIT 1 TO

PETITIONER'S REPLY BRIEF

SUBMITTED ON BEHALF OF DOMINION ENERGY BRAYTON POINT, LLC

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EXHIBIT 1

BRAYTON POINT STATION

REVIEW OF 2/26/2007 MEMORANDUM (EXHIBIT R15) DESCRIBING REGION 1'S PRODUCTION FOREGONE CALCULATIONS

ENVIRONMENTAL APPEALS BOARD

APPEAL NPDES 07-01, EXHIBIT R15, AR 4068

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EXECUTIVE SUMMARY

Production foregone has been used in 316(b) studies throughout the nation to estimate the biomass that would have been produced by the eggs, larvae and young fish lost due to entrainment and impingement at power stations. The established methodology for calculating production foregone is to apply an equation developed by Rago (1984). Production foregone calculations were performed by consultants to EPA Region 1 (hereafter Region 1) and relied on in the development of the Brayton Point Station NPDES permit (October 2003). However, Region 1 incorrectly implemented Rago's equation with the result being overestimated values of production foregone. Region 1 was made aware of these errors in detail in October 2002 (AR 3263, Ex. 33, vol. II, Tab 11 at II-8 to II-19), agreed that problems existed with its production foregone estimates (AR 3346), and now indicates that its errors have been corrected in the document (AR 4068) that is reviewed by this report. In its re-analysis of production foregone, Region 1 committed nearly all the same errors as in its first attempt and continues to overestimate production foregone by over 200 times.

The Rago (1984) equation computes a growth rate over each life stage based on the initial and ending weights for the stage. Instead of applying the initial and final weights in its calculations, however, Region 1 used estimates of weights at the midpoints of successive life stages. This error alone caused Region 1 to conclude that 78% of the production foregone resulting from Brayton Point Station operations comes from growth during the egg stage. However, post-spawn eggs do not increase in weight and a recent communication with the author of the paper referenced by Region 1 as the source for its production foregone equations confirmed that increase in weight and thus production foregone during the egg stage should be zero (P.J. Rago, personal communication, NOAA Fisheries National Marine Fisheries Service, April 5, 2007). Region 1 further compounded its misapplication of the Rago (1984) equation by using gross overestimates of the midpoint weights of early life stages such as for eggs and larvae. For example, for tautog larvae, Region 1 used a value that is 56 times larger than the one reported in the scientific literature.

The combined effect of Region 1's errors is a gross overestimation of production foregone due to Brayton Point Station operations. Region 1's current estimate of 51.5 millions pounds of production foregone attributable to current operations, which was revised from 69 million pounds, is still well over 200 times the 215,000 pounds per year that results when the errors in its calculations are corrected.

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1.0 INTRODUCTION

This document provides a review of the production foregone estimate attributed to Brayton Point Generating Station (Somerset, MA) provided in a memorandum from EPA Region 1's consultants, Liz Strange and Dave Cacela (of Stratus Consulting Inc.), to Phil Colarusso and Mark Stein (of EPA – New England) dated 2/26/2007. This memorandum has been added to the Environmental Appeals Board (EAB) Appeal Docket pertaining to the Brayton Point Station NPDES Permit Appeal (Appeal Number: NPDES 07-01) as Filing #26, Exhibit R15, AR 4068. HDR|LMS (formerly Lawler, Matusky and Skelly Engineers, LLP [LMS]) is knowledgeable regarding Brayton Point Station §316(a) and (b) issues, having prepared the May 2001 Partial §316(a) and (b) Demonstration (AR 511), the November 2001 Final §316(a) and (b) Demonstration (AR 555), the LMS Response to MA00003654 Determinations Document (AR 3263), as well as a number of technical documents relating to the Brayton Point Station Permit appeal and other environmental analyses. HDR|LMS is particularly knowledgeable regarding Brayton Point Station production foregone calculations having completed such analyses for the Station in support of the permit application and having reviewed Region 1's previous estimates of production foregone (AR 192). Accordingly, HDR|LMS is qualified to provide comment on this most recent memo detailing the production foregone estimates relied on in the development of the Brayton Point Station NPDES permit.

Region 1's most recent description of its production foregone calculations and estimates, provided to EAB on March 5, 2007, is reviewed herein. First, production foregone is defined and its calculation is explained. This is followed by a description of the major errors evident in the Region's most recent filing pertaining to production foregone. Finally, corrected production foregone estimates are calculated using the Region's impingement and entrainment data, with the correct values for early life stage weights input to the Rago (1984) production foregone equation and the results are compared to the Region's reported estimates.

2.0 PRODUCTION FOREGONE

2.1 Production Foregone Explained

Production foregone is commonly used to quantify the losses of organisms due to impingement and entrainment. It is the amount of biomass that would have been added to the source population if the entrained and impinged organisms had instead died from natural or other causes (e.g. fishing). There is an established and widely used methodology for calculating the future production of entrained or impinged organisms of a given age class or life stage over their life time. This methodology was developed by Rago (1984) and used by both Region 1 and HDR|LMS to calculate production foregone associated with Brayton Point Station operations. However, as discussed in detail below, Region 1 applied Rago's method incorrectly.

2.2 EPA Region 1 Production Foregone Calculation Errors

Examination of Region 1's analysis reveals two types of errors in its production foregone calculations. First, Region 1 made incorrect assumptions in its calculation of growth rates that resulted in erroneous accumulation of production foregone (as in the case of eggs) and inflated production foregone (as in post-egg life stages for many species). Second, Region 1 used biologically unrealistic values for early life stage weights, which compounded with the first error to produce grossly inflated (by more than 200 times) estimates of production foregone. These errors are described in detail below.

2.2.1 Growth Rate and Initial Biomass Errors

The production foregone equation accumulates production (i.e., elaboration of fish tissue or biomass) of organisms lost to entrainment and impingement assuming they had not been intercepted by a cooling water intake. It does this by growing individual organisms over time, life stage by life stage, until they die from natural and other non-Station causes (e.g. fishing).

Among other information, the calculation of production foregone requires the weight of the average individual at the start of each life stage (e.g., larvae, age-1, age-2, age-3, etc.). These initial weights are used in conjunction with growth rates to calculate the accumulation of biomass over each life stage. Life-stage growth rates are logically calculated using the start and end weights of the stage. However, instead of using start and end weights, Region 1 used the weights at the midpoints of successive stages in its calculation of growth rates. Region 1 also mistakenly used mid-stage weights to calculate initial biomass of a life stage when the initial weight should have been used. For example, Region 1 calculated production due to age-2 fish using age-2.5 fish weight as a start weight and age-3.5 fish weight as the end weight, when the correct values would have been age-2 start weight and age-3 start weight. This erroneous application of the Rago (1984) equation artificially inflates the production foregone over each life stage.

Region 1's use of mid-stage weights in lieu of start and end weights is incorrect. This error is a matter of scientific fact, not scientific opinion. In fact, Dr. Paul J. Rago, the author of Rago (1984) which was relied on by Region 1 for its production foregone equation, confirmed that it is inappropriate to apply mid-stage weights for initial weights in the calculation of production, as was done by Region 1 (P.J. Rago, personal communication, NOAA Fisheries National Marine Fisheries Service, April 5, 2007). This error is described further in the following discussion of Rago's production foregone equations.

Rago (1984) provides the following equation for calculation of production (P) for an individual life stage:

$$P = G\overline{B} \qquad \text{Equation 1}$$

where:

G	=	the instantaneous growth rate
$\overline{B}$	=	the average biomass

The average biomass, $\overline{B}$, is:

$$\overline{B} = \frac{B_0(e^{G-Z} - 1)}{G - Z} \qquad \text{Equation 2}$$

where:

Z	=	instantaneous mortality rate
B_0	=	initial biomass at start of the life stage.

The initial biomass, B_0, is calculated from:

$$B_0 = N_0 \overline{W}_0 \qquad \text{Equation 3}$$

where:

N_0 = number of individuals at the start of the life stage

$\overline{W}_0$ = average weight of individuals at the start of the life stage.

Combining the above three equations yields the following expression of Equation 5 from Rago (1984) for individual life stages:

$$P = \frac{GN_0\overline{W}_0(e^{G-Z}-1)}{G-Z} \qquad \text{Equation 4}$$

It is evident from Equation 4 that the correct weight parameter is the average weight of individuals at the start of the life stage, $\overline{W}_0$, not the average or mid-stage weight over the duration of the life stage used by Region 1. Region 1's use of the life-stage average or mid-stage weight instead of the initial weight in Equation 4 tends to inflate the resulting estimates of production foregone because the average weight of an individual at the midpoint of a life stage is nearly always substantially greater than the weight at the beginning.

Region 1's incorrect use of mid-stage weights in lieu of start and end weights in the calculation of growth rates has a particularly troubling consequence for the calculation of production foregone due to entrainment of eggs. Region 1's approach does not recognize that while eggs develop and produce new tissue, all of the energy resource for such growth and development is already contained within the egg upon being released from the adult female. As a result, eggs do not increase in weight between the time they are released from the female and the time they hatch; hence, eggs do not produce new biomass. Consequently, production foregone during the egg stage is correctly zero (in Equation 4, when $G = 0$ it follows that $P = 0$, or production foregone is zero). This fact was corroborated by Dr. Paul J. Rago, the author of Rago (1984) (P.J. Rago, personal communication, NOAA Fisheries National Marine Fisheries Service, April 5, 2007). The production foregone due to the entrainment of eggs begins to accumulate after the egg stage, based on the proportion of eggs that survive and go on to grow as exogenously feeding larvae, juveniles and adults.

2.2.2 Biologically Unrealistic Weights

The production foregone calculation requires estimates of the weights of early and subsequent life stages of fish. If the values used for these weights are unrealistic the resulting production foregone calculations will be inaccurate. As discussed in detail below, a number of the weights used by Region 1 in its production foregone calculations were extreme overestimates and not consistent with fundamental principles and information readily available in the scientific literature. It is clear based on a cursory review of Region 1's life history parameters (Tables 3-22 of AR 4068) that overestimated values were applied for a number of species. For example, in Table 7 of AR 4068, which provides life history parameters for tautog, the larval weight is reported to be 0.022 pounds or approximately 10 grams. Using the juvenile length-weight relationship provided by Hostetter and Munroe (1993) shows that this larva would measure approximately 75.0 mm, yet studies have shown that tautog larvae measure 2.2 to 30 mm (AR 3263, Ex. 33, vol. II, Tab 11 at II-17). Furthermore, because weight increases exponentially with growth rate, the average weight used by Region 1 in its production foregone calculations is 56 times higher than the average weight of tautog larvae and more than 24,000 times the initial weight which should have been used. Based on this finding, the following methods were implemented by HDR|LMS to ground truth the egg and larval weights used in Region 1's production foregone calculations.

2.2.2.1 *Egg Weights*

The egg weights used by Region 1 were evaluated relative to the assumption that they should weigh approximately the same as an equivalent volume of water. This method was found to provide reasonable approximations in AR 3263, Ex. 33, vol. II, Tab 11 at II-13 to II-15 and has been used in peer-reviewed scientific studies such as McGurk (1984). For eggs, volume (V) may be calculated as $V = \pi\ d_1\ d_2\ d_3\ /6$ where d_1 = major axis, d_2 = largest minor axis, and d_3 = smallest minor axis. For spherical eggs this reduces to $V = \pi d^3/6$ where d = diameter. The weight of an egg can then be calculated by multiplying the egg's volume by the density of water, i.e., 1 gram/cm^3. This calculation was performed for eggs of each species based on diameters available from various literature sources, but predominately USFWS (1978) and Able and Fahay (1998).

Results from this analysis, presented in Table 1, show that Region 1 overestimated egg weights of two species, seaboard goby and silver hake, by factors of 86 and 23 times, respectively. Three other species (American sand lance, Atlantic silverside and winter flounder) appear to be overestimated by factors ranging from 1.9 to 2.2. Egg weights for weakfish and some other species appear to have been underestimated.

2.2.2.2 *Larval Weights*

Larval weights used by Region 1 in its calculation of production foregone were also reviewed. Scientific studies rarely report the average wet weight of larvae. As a result, HDR|LMS estimated larval weights by fitting a length-weight equation over the larval stage based on information available for eggs, larvae and juveniles. Data sources included the egg weights calculated in the previous section and lengths and weights contained in the November 2001 Final §316(a) and (b) Demonstration (AR 555) life tables (these life tables were also relied on by Region 1 to generate Tables 3 through 22 of AR 4068). The process produced length-weight equations that could be used to estimate mid-stage-weights to compare to Region 1's values and weights at the start of the larval stage for calculation of production foregone with correction of the errors made by Region 1. The typical length-weight equation is in the following form:

$$W = \alpha L^{\beta} \qquad \text{Equation 5}$$

where:

W = weight in grams
L = length in mm

Species-specific coefficients for α and β were calculated for larvae by fitting the linear form of Equation 5:

$$\ln W = \ln \alpha + \beta \ln L \qquad \text{Equation 6}$$

to available data. Larval start lengths were taken from the AR 555 life history tables while larval start weights were assumed to be equivalent to the corrected egg weights. Larval end lengths and weights were calculated using the juvenile and adult length-weight equations underlying the AR 555 life table. These length-weight equations were utilized because AR 6068 Tables 3 through 22 contain mid-stage weights instead of start and end weights.

Table 2 compares the average larval weights used by Region 1 with the average larval weights based on early life stage length-weight equations calculated as described above (larval weights for winter flounder, tautog and scup were readily available from the scientific literature and thus, it was not necessary to calculate them). Comparing Region 1's average life-stage weights to those calculated by HDR|LMS shows that both winter flounder and weakfish larval weights were overestimated by thousands of times (2,248 to 40,903). Hogchoker, tautog, threespine stickleback and windowpane were overestimated by tens of times (38 to 119) and larval weights of the remaining species were either moderately overestimated (5 species) or underestimated (6 species).

2.2.3 Combined Influence of Errors

HDR|LMS calculated production foregone estimates based on the same entrainment and impingement data and life history parameters used by Region 1 in AR 4068 but with values for weights, growth rates, and initial biomass corrected for Region 1's errors. The results for individual species (Table 3) show that the combined effect of the Region's errors is frequent overestimation, sometimes by hundreds of times, of the production foregone due to entrainment and impingement at Brayton Point Station. In fact, the Region overstated total production foregone by over 200 times. As a result, its most recent estimate of 51,500,000 pounds of production forgone due to current Brayton Point Station operations reduces to approximately 215,000 pounds when corrected for the errors in the Region's calculations.

3.0 CONCLUSION

Region 1 continues to overestimate production foregone attributable to Brayton Point Station by more than 200 times. The errors made by Region 1 are not a matter of interpretation because they are inconsistent with readily available biological data and basic mathematics.

4.0 LITERATURE CITED

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5.0 TABLES

Table 1. Comparison of expected egg weight with values assumed by Region 1

Species	Region 1	Expected Egg Parameters			Region 1 ÷ Expected
	Weight lbs · wet	Egg Diameter* (mm)	Weight grams · wet	Weight lbs · wet	
Alewife	0.0000013	1.035	0.00058	0.0000013	1.0
Atlantic menhaden	0.0000048	1.6	0.0021	0.0000047	1.0
American sand lance	0.0000013	0.79	0.00026	0.00000057	2.2
Atlantic silverside	0.0000047	1.25	0.0010	0.0000023	2.1
Bay anchovy	0.00000052	0.945	0.00044	0.00000097	0.5
Blueback herring	0.0000012	0.99	0.00051	0.0000011	1.0
Butterfish	0.00000040	0.77	0.00024	0.00000053	0.8
Hogchoker	0.00000049	0.79	0.00026	0.00000057	0.9
Rainbow smelt	0.00000099	1	0.00052	0.0000012	0.9
Scup	0.00000077	0.9	0.00038	0.00000084	0.9
Seaboard goby	0.000016	0.55	0.00009	0.00000019	86
Silver hake	0.000020	0.915	0.00040	0.00000088	23
Striped killifish	0.000018	2.62	0.0094	0.000021	0.9
Tautog	0.0000012	0.92	0.00041	0.00000090	1.4
Threespine stickleback	0.00022**	1.7	0.0026	0.0000057	39
Weakfish	0.0000012	1.6	0.0021	0.0000047	0.2
White perch	0.00000084	0.895	0.00038	0.00000083	1.0
Windowpane	0.0000015	1.15	0.00080	0.0000018	0.9
Winter flounder	0.0000012	0.8	0.00027	0.00000059	1.9

*Egg diameter was obtained from various literature sources, but predominately USFWS (1978) and Able and Fahay (1998).
**Region 1's AR 4068 did not provide an egg weight; value is from the EPA Brayton Point Station Case Study.

Table 2. Comparison of expected larval weights with values assumed by Region 1

Species	Region 1 – Average Weight		Expected Larval Weights (grams)*			Region 1 ÷ Expected
	(pounds)	(grams)	Start of Life Stage	End of Life Stage	Average Weight	
Alewife	0.0000014	0.00064	0.00058	0.12	0.036	0.02
American sand lance	0.0000014	0.00063	0.00026	0.053	0.015	0.04
Atlantic menhaden	0.0000053	0.0024	0.0021	0.31	0.11	0.02
Atlantic silverside	0.0000052	0.0024	0.0010	0.0023	0.0017	1.4
Bay anchovy	0.00000057	0.00026	0.00044	0.02	0.0076	0.03
Hogchoker	0.0011	0.50	0.00026	0.011	0.0042	119
Rainbow smelt	0.0011	0.50	0.00052	0.11	0.033	15
Scup	0.0011	0.50	0.00038	0.15	0.048	11
Seaboard goby	0.000018	0.0082	0.000087	0.0039	0.0014	6
Silver hake	0.000022	0.010	0.00040	0.23	0.072	0.14
Tautog	0.022	10	0.00041	0.63	0.18	56
Threespine stickleback	0.0011	0.50	0.0026	0.029	0.013	38
Weakfish	0.065	30	0.0021	0.013	0.0075	3,923
White perch	0.0011	0.50	0.00038	0.26	0.075	6.6
Windowpane	0.0017	0.75	0.00080	0.03	0.011	71
Winter flounder -stage1	0.0044	2.0	0.00013	0.00011	0.00012	16,393
Winter flounder -stage2	0.011	5.0	0.00011	0.0013	0.00012	40,902
Winter flounder -stage3	0.018	8.0	0.00013	0.0038	0.0013	6,234
Winter flounder -stage4	0.022	10.0	0.0038	0.005	0.0044	2,248
Alewife	0.0000014	0.00064	0.00058	0.12	0.036	0.02

*Values for winter flounder, tautog and scup were readily available from the literature (see AR 3263, Ex. 33, vol. II, Tab 11 at II-15 to II-17 for details); values for all other species were calculated as described in section 2.2.2.2.