

Transmittal Memorandum

To: Phil Colarusso and Mark Stein, EPA-New England
From: Liz Strange and Dave Cacela, Stratus Consulting Inc.
Date: 2/26/2007
Subject: Production Foregone Data Underlying the Analysis Described in 9/16/2003 Memorandum from Stratus Consulting to Phil Colarusso

1. Introduction

This memorandum provides technical data that are the basis of our analyses of impingement and entrainment (I&E) at Brayton Point Station (BPS) that we reported in the 9/16/2003 memorandum from Stratus Consulting to Phil Colarusso. This memorandum does not report any new data or analyses that are more recent than those reported in Stratus Consulting (2003); it simply provides certain details about the analysis that were not included in Stratus Consulting (2003).

Stratus Consulting (2003) reported the results of a reanalysis of BPS I&E losses that we conducted after we received technical comments during the period of formal review of the BPS case study (EPA 2002). Stratus Consulting (2003) reported the results of the reanalysis in aggregate terms only, while this memorandum reports additional details about certain elements of the reanalysis. In particular, this memorandum provides "the production foregone numbers" that BPS has requested. We understand the expression "the production foregone numbers" to include production foregone estimates itemized by individual species. In addition, we are providing the estimated I&E loss rates that underlie the production foregone estimates and the life history parameters that inform the estimation of production foregone. These elements are provided in Section 2 of this memorandum.

2. Elements of the Production Foregone Estimates

Table 1 reports the estimates of mean annual I&E loss rates at BPS during 1974-1983, including considerations of facility flow characteristics that are described in Part F of EPA (2002). The estimated loss rates presented in Table 1 represent the mean annual total mortality expressed as individuals killed.

The mathematical models described in the BPS case study (EPA 2002; Chapter A5) were used to translate the annual loss rates (Table 1) into estimates of production foregone (Table 2).

Tables 3-22 report the life history parameters that were used in the reanalysis (Stratus Consulting 2003). Some of the values in Tables 3-22 are unchanged relative to EPA (2002), but many values differ from those in EPA (2002). The values that differ were changed to agree with those in PG&E National Energy Group (2001), as suggested by comments that we received during the formal review of EPA (2002), including suggestions from BPS and its technical advisors.

Table 1. Estimates of mean annual impingement and entrainment loss rates at Brayton Point Station derived from empirical studies conducted 1974-1983.

Species	Stage	Entrained	Impinged
Atlantic silverside	Age01		9,427
White perch	Age01		1,304
Silver hake	Age01		3,165
Winter flounder	Age01		6,850
Hogchoker	Age01		3,992
Tautog	Age01		809
Windowpane	Age01		612
Other forage	Age01		4,176
Threespine stickleback	Age01		3,525
Bay anchovy	Age01		1,483
Butterfish	Age01		632
Weakfish	Age01		286
Striped killifish	Age01		287
Rainbow smelt	Age01		798
Atlantic menhaden	Age01		12,134
Alewife	Age01		4,023
Blueback herring	Age01		1,186
Bay anchovy	Egg	4,488,180,285	
Bay anchovy	Larvae	4,445,789,370	
Tautog	Egg	3,525,964,319	
Atlantic menhaden	Egg	559,162,276	
Seaboard goby	Larvae	396,759,106	
Winter flounder	Larvae2	291,139,993	
Winter flounder	Egg	243,884,663	
Windowpane	Egg	221,074,537	

Table 1. Estimates of mean annual impingement and entrainment loss rates at Brayton Point Station derived from empirical studies conducted 1974-1983.

Species	Stage	Entrained	Impinged
Winter flounder	Larvae1	122,534,989	
Atlantic menhaden	Larvae	115,445,229	
Hogchoker	Egg	93,124,139	
Winter flounder	Larvae3	81,998,834	
American sand lance	Larvae	68,513,405	
Weakfish	Egg	44,574,638	
Tautog	Larvae	25,379,878	
Atlantic silverside	Larvae	18,221,701	
Weakfish	Larvae	12,129,799	
Windowpane	Larvae	5,201,122	
Hogchoker	Larvae	4,480,794	
Rainbow smelt	Larvae	2,465,677	
Scup	Egg	2,056,099	
Winter flounder	Larvae	1,156,597	
Rainbow smelt	Egg	771,454	
Alewife	Larvae	679,389	
White perch	Egg	610,444	
Seaboard goby	Egg	575,693	
Alewife	Egg	411,108	
Atlantic silverside	Egg	288,395	
Scup	Larvae	141,584	
American sand lance	Egg	109,094	
White perch	Larvae	46,696	
Silver hake	Larvae	22,000	
Threespine stickleback	Larvae	12,884	
Silver hake	Egg	11,423	

Table 2. Estimated mean annual production foregone (PF; pounds) due to I&E at Brayton Point Station.

Species	PF due to entrainment	PF due to impingement
All species Sum	51,542,130	429
alewife	222	46
American sand lance	709	0
Atlantic menhaden	491,171	35
Atlantic silverside	2,307	13
bay anchovy	57,109	0
blueback herring	0	22
butterfish	0	16
hogchoker	70,709	1
other forage	0	1
rainbow smelt	4,344	7
scup	1,112	0
seaboard goby	532	0
silver hake	9	25
striped killifish	0	3
tautog	43,417,350	6
threespine stickleback	21	1
weakfish	3,666,365	1
white perch	544	0
windowpane	189,801	9
winter flounder	3,639,829	241

Table 3. Life history parameters used to model production foregone of winter flounder

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.75	0.288	0	0	0.00000115
Larvae1	0.129	2.05	0	0	0.00441
Larvae2	0.0328	3.42	0	0	0.011
Larvae3	0.0296	3.52	0	0	0.0176
Larvae4	0.838	0.177	0	0	0.022
Juvenile	0.0927	2.38	0	0	0.033
Age01	0.329	1.1	0.00657	1	0.208
Age02	0.365	0.924	0.0825	1	0.562
Age03	0.669	0.2	0.201	1	0.997
Age04	0.589	0.2	0.33	1	1.42
Age05	0.589	0.2	0.33	1	1.78
Age06	0.589	0.2	0.33	1	2.07
Age07	0.589	0.2	0.33	1	2.29
Age08	0.589	0.2	0.33	1	2.45
Age09	0.589	0.2	0.33	1	2.57
Age10	0.589	0.2	0.33	1	2.65
Age11	0.589	0.2	0.33	1	2.71
Age12	0.589	0.2	0.33	1	2.75
Age13	0.589	0.2	0.33	1	2.78
Age14	0.589	0.2	0.33	1	2.8
Age15	0.589	0.2	0.33	1	2.82
Age16	0.589	0.2	0.33	1	2.83

Table 4. Life history parameters used to model production foregone of seaboard goby

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.75	0.288	0	0	0.0000164
Larvae	0.0167	4.09	0	0	0.000018
Juvenile	0.1	2.3	0	0	0.000485
Age01	0.0783	2.55	0	0	0.00205

Table 5. Life history parameters used to model production foregone of hogchoker

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.353	1.04	0	0	4.87e-07
Larvae	0.0055	5.2	0	0	0.0011
Juvenile	0.0988	2.31	0	0	0.00207
Age01	0.0771	2.56	0	0	0.0113
Age02	0.494	0.705	0	0	0.0313
Age03	0.494	0.705	0	0	0.061
Age04	0.494	0.705	0	0	0.0976
Age05	0.494	0.705	0	0	0.138
Age06	0.494	0.705	0	0	0.178

Table 6. Life history parameters used to model production foregone of windowpane

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.243	1.41	0	0	1.54E-06
Larvae	0.00092	6.99	0	0	0.00165
Juvenile	0.0508	2.98	0	0	0.00223
Age01	0.657	0.42	0	0	0.0325
Age02	0.657	0.42	0	0	0.122
Age03	0.657	0.42	0	0	0.265
Age04	0.657	0.42	0	0	0.433
Age05	0.657	0.42	0	0	0.603
Age06	0.595	0.42	0.0986	1	0.761
Age07	0.595	0.42	0.0986	1	0.899
Age08	0.595	0.42	0.0986	1	1.01
Age09	0.595	0.42	0.0986	1	1.11
Age10	0.595	0.42	0.0986	1	1.19

Table 7. Life history parameters used to model production foregone of tautog

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.245	1.4	0	0	1.23E-06
Larvae	0.0029	5.86	0	0	0.022
Juvenile	0.0066	5.02	0	0	0.0637
Age01	0.84	0.175	0	0	0.217
Age02	0.84	0.175	0	0	0.44
Age03	0.84	0.175	0	0	0.734
Age04	0.84	0.175	0	0	1.08
Age05	0.84	0.175	0	0	1.48
Age06	0.84	0.175	0	0	1.89
Age07	0.84	0.175	0	0	2.32
Age08	0.84	0.175	0	0	2.76
Age09	0.66	0.175	0.24	1	3.18
Age10	0.66	0.175	0.24	1	3.6
Age11	0.66	0.175	0.24	1	4
Age12	0.66	0.175	0.24	1	4.38
Age13	0.66	0.175	0.24	1	4.73
Age14	0.66	0.175	0.24	1	5.07
Age15	0.66	0.175	0.24	1	5.38
Age16	0.66	0.175	0.24	1	5.67
Age17	0.66	0.175	0.24	1	5.94
Age18	0.66	0.175	0.24	1	6.19
Age19	0.66	0.175	0.24	1	6.42
Age20	0.66	0.175	0.24	1	6.63
Age21	0.66	0.175	0.24	1	6.82
Age22	0.66	0.175	0.24	1	6.99
Age23	0.66	0.175	0.24	1	7.15
Age24	0.66	0.175	0.24	1	10

Table 8. Life history parameters used to model production foregone of scup

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.24	1.43	0	0	7.73E-07
Larvae	0.011	4.55	0	0	0.0011
Juvenile	0.035	3.36	0	0	0.028
Age01	0.682	0.383	0	0	0.132
Age02	0.682	0.383	0	0	0.322
Age03	0.526	0.383	0.26	1	0.572
Age04	0.526	0.383	0.26	1	0.845
Age05	0.526	0.383	0.26	1	1.12
Age06	0.526	0.383	0.26	1	1.37
Age07	0.526	0.383	0.26	1	1.59
Age08	0.526	0.383	0.26	1	1.78
Age09	0.526	0.383	0.26	1	1.94
Age10	0.526	0.383	0.26	1	2.07
Age11	0.526	0.383	0.26	1	2.23

Table 9. Life history parameters used to model production foregone of butterfish

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.1	2.3	0	0	0.000000396
Larvae	0.0013	6.64	0	0	0.000000436
Juvenile	0.4	0.916	0	0	0.000251
Age01	0.34	0.8	0.28	0.5	0.0272
Age02	0.34	0.8	0.28	1	0.0986
Age03	0.34	0.8	0.28	1	0.944

Table 10. Life history parameters used to model production foregone of bay anchovy

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.331	1.1	0	0	5.17E-07
Larvae	0.00075	7.19	0	0	5.69E-07
Juvenile	0.124	2.09	0	0	0.00104
Age01	0.1	2.3	0	0	0.0037
Age02	0.1	2.3	0	0	0.00765
Age03	0.1	2.3	0	0	0.0126

Table 11. Life history parameters used to model production foregone of alewife

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.581	0.544	0	0	1.28E-06
Larvae	0.0041	5.5	0	0	1.41E-06
Juvenile	0.0763	2.57	0	0	0.00478
Age01	0.355	1.04	0	0	0.0443
Age02	0.355	1.04	0	0	0.139
Age03	0.355	1.04	0	0	0.264
Age04	0.355	1.04	0	0	0.386
Age05	0.355	1.04	0	0	0.489
Age06	0.355	1.04	0	0	0.568
Age07	0.355	1.04	0	0	0.626
Age08	0.355	1.04	0	0	0.667
Age09	0.355	1.04	0	0	0.696

Table 12. Life history parameters used to model production foregone of other forage species

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
egg	0.352	1.04	0	0	1.86E-08
Larvae	0.00045	7.7	0	0	1.58E-06
Juvenile	0.275	1.29	0	0	0.000481
Age01	0.197	1.62	0	0	0.00381
Age02	0.197	1.62	0	0	0.00496
Age03	0.197	1.62	0	0	0.00505

Table 13. Life history parameters used to model production foregone of silver hake

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.24	1.43	0	0	2.03E-05
Larvae	0.0013	6.62	0	0	2.23E-05
Juvenile	0.0102	4.58	0	0	0.00516
Age01	0.67	0.4	0	0	0.0729
Age02	0.67	0.4	0	0	0.242
Age03	0.449	0.4	0.4	1	0.456
Age04	0.449	0.4	0.4	1	0.646
Age05	0.449	0.4	0.4	1	0.788
Age06	0.449	0.4	0.4	1	0.889
Age07	0.449	0.4	0.4	1	0.958
Age08	0.449	0.4	0.4	1	1
Age09	0.449	0.4	0.4	1	1.03
Age10	0.449	0.4	0.4	1	1.05
Age11	0.449	0.4	0.4	1	1.06
Age12	0.449	0.4	0.4	1	1.06

Table 14. Life history parameters used to model production foregone of weakfish

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.608	0.498	0	0	1.15E-06
Larvae	0.058	2.84	0	0	0.065
Juvenile1	0.034	3.39	0	0	0.13
Juvenile2	0.004	5.47	0	0	0.195
Age01	0.389	0.694	0.25	1	0.26
Age02	0.292	0.73	0.5	1	0.68
Age03	0.314	0.657	0.5	1	1.12
Age04	0.364	0.511	0.5	1	1.79
Age05	0.364	0.511	0.5	1	2.91
Age06	0.364	0.511	0.5	1	6.21
Age07	0.364	0.511	0.5	1	7.14
Age08	0.364	0.511	0.5	1	9.16
Age09	0.364	0.511	0.5	1	10.8
Age10	0.364	0.511	0.5	1	12.5
Age11	0.364	0.511	0.5	1	12.5
Age12	0.364	0.511	0.5	1	12.5
Age13	0.364	0.511	0.5	1	12.5
Age14	0.364	0.511	0.5	1	12.5
Age15	0.364	0.511	0.5	1	12.5

Table 15. Life history parameters used to model production foregone of white perch

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.242	1.42	0	0	8.42E-07
Larvae	0.0102	4.59	0	0	0.0011
Juvenile	0.00012	9.06	0	0	0.00302
Age01	0.5	0.693	0	0	0.0516
Age02	0.5	0.693	0	0	0.156
Age03	0.5	0.543	0.15	1	0.248
Age04	0.5	0.543	0.15	1	0.331
Age05	0.2	1.46	0.15	1	0.423
Age06	0.2	1.46	0.15	1	0.523
Age07	0.2	1.46	0.15	1	0.613
Age08	0.2	1.46	0.15	1	0.658
Age09	0.2	1.46	0.15	1	0.794

Table 16. Life history parameters used to model production foregone of striped killifish

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.1	2.3	0	0	0.000018
Larvae	0.05	3	0	0	1.82E-05
Juvenile	0.4	0.916	0	0	0.000157
Age01	0.46	0.777	0	0	0.0121
Age02	0.46	0.777	0	0	0.0327
Age03	0.46	0.777	0	0	0.0551
Age04	0.46	0.777	0	0	0.0778
Age05	0.46	0.777	0	0	0.0967
Age06	0.46	0.777	0	0	0.113
Age07	0.46	0.777	0	0	0.158

Table 17. Life history parameters used to model production foregone of rainbow smelt

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.012	4.44	0	0	9.9E-07
Larvae	0.044	3.12	0	0	0.0011
Juvenile	0.249	1.39	0	0	0.00395
Age01	0.368	1	0	0	0.0182
Age02	0.368	1	0	0	0.046
Age03	0.368	1	0	0	0.085
Age04	0.368	1	0	0	0.131
Age05	0.368	1	0	0	0.18
Age06	0.368	1	0	0	0.228

Table 18. Life history parameters used to model production foregone of blueback herring

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.572	0.558	0	0	1.15E-06
Yolksac larvae	0.16	1.83	0	0	0.00321
Post-yolksac larvae	0.176	1.74	0	0	0.0064
Juvenile1	0.044	3.13	0	0	0.00959
Juvenile2	0.044	3.13	0	0	0.0128
Age01	0.741	0.3	0	0	0.016
Age02	0.741	0.3	0	0	0.0905
Age03	0.741	0.3	0	0	0.204
Age04	0.407	0.9	0	0	0.318
Age05	0.223	1.5	0	0	0.414
Age06	0.223	1.5	0	0	0.488
Age07	0.223	1.5	0	0	0.54
Age08	0.223	1.5	0	0	0.576

Table 19. Life history parameters used to model production foregone of American sand lance

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.243	1.41	0	0	1.26E-06
Larvae	0.051	2.97	0	0	1.39E-06
Juvenile	0.055	2.9	0	0	0.00119
Age01	0.152	1.89	0	0	0.00384
Age02	0.695	0.364	0	0	0.0073
Age03	0.695	0.364	0	0	0.0113
Age04	0.695	0.364	0	0	0.0153
Age05	0.695	0.364	0	0	0.0191
Age06	0.695	0.364	0	0	0.0225
Age07	0.487	0.72	0	0	0.0255
Age08	0.487	0.72	0	0	0.028
Age09	0.487	0.72	0	0	0.0301
Age10	0.487	0.72	0	0	0.0319
Age11	0.487	0.72	0	0	0.0333

Table 20. Life history parameters used to model production foregone of Atlantic menhaden

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.3	1.2	0	0	4.82E-06
Larvae	0.0114	4.47	0	0	5.3E-06
Juvenile	0.0021	6.19	0	0	0.000684
Age01	0.583	0.54	0	0	0.0251
Age02	0.208	0.45	1.12	1	0.235
Age03	0.208	0.45	1.12	1	0.402
Age04	0.208	0.45	1.12	1	0.586
Age05	0.208	0.45	1.12	1	0.863
Age06	0.208	0.45	1.12	1	1.08
Age07	0.208	0.45	1.12	1	1.27
Age08	0.208	0.45	1.12	1	1.43

Table 21. Life history parameters used to model production foregone of Atlantic silverside

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Egg	0.243	1.41	0	0	4.73E-06
Larvae	0.003	5.81	0	0	5.2E-06
Juvenile	0.0722	2.63	0	0	0.0049
Age01	0.05	3	0	0	0.0205
Age02	0.001	6.91	0	0	0.0349

Table 22. Life history parameters used to model production foregone of threespine stickleback

Stage	Survival	Natural mortality	Fishing mortality	Fraction vulnerable to fishery	Weight (lbs)
Juvenile	0.182	1.7	0	0	0.00377
Age01	0.242	1.42	0	0	0.00917
Age02	0.242	1.42	0	0	0.0112
Age03	0.242	1.42	0	0	0.0116

Literature Cited

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