APPENDIX H

Technical Memorandum For The Record
By: Gerald M. Szal
Subject: Pilgrim Nuclear Power Station: review of intake and discharge effects to finfish
Date: December 5, 2005

Estimated impacts to aquatic life from the operation of the Pilgrim Nuclear Power Station are divided into two categories: those from the intake of cooling water, and those from the discharge of heated effluent. Intake effects are further divided into two categories: those from impingement on intake screens at the entry of the intake bay; and those from entrainment of fish eggs and larvae through the facility. Discharge effects discussed include those from the cooling water discharge and those from the heated backwash used to control biofouling in the intake bays.

Intake Effects

Impingement

Effects to winter flounder:
Impingement effects to this species are typically small at the Pilgrim facility. An estimated total of slightly over 2,000 winter flounder were impinged in year 2004. Most, if not all, of these were young of the year. This is the second highest impingement rate in the past 25 years of monitoring, but does not appear to represent a significant impact to the population.

Effects to other finfish species:
The following fish species were considered those suffering the greatest numerical losses due to impingement over the last 11 years of monitoring at Pilgrim (Table 3, Impingement Section, Environmental Protection Group 2005):

Table 1

Year	Atlantic silverside	Atlantic menhaden	blueback herring	grubby	rainbow smelt	alewife
1994	36,498	58	269	1,094	9,464	123
1995	13,085	1,560	1,244	648	2,191	39,884
1996	16,615	2,168	2,462	1,347	3,728	216
1997	6,303	1,329	424	405	1,978	317
1998	6,773	1,423	134	335	1,656	158
1999	8,577	42,686	550	628	875	610
2000	25,665	34,354	5,919	1,105	13	2,443
2001	4,987	3,599	229	517	879	1,618
2002	4,430	53,304	943	1,087	335	334
2003	23,149	119,041	1,968	237	532	438
2004	13,107	10,431	2,046	2,257	1,092	145

Of particular interest are the rainbow smelt. These fish are an anadromous species and smelt impinged at Pilgrim most probably come from the Jones River population. Although there are two other rainbow smelt runs (Town Brook and Eel River) in the Plymouth/Kinston/Duxbury Bay area, they are apparently quite small in comparison to that from the Jones River (based on pers. comm., Brad Chase, MA Division of Marine Fisheries [DMF] to Gerald Szal, DEP). Rainbow smelt are not known to reproduce elsewhere in streams entering Cape Cod Bay or in streams elsewhere on Cape Cod.

During the late 1970s, there were a number of rainbow smelt impingement events at the Pilgrim facility. In 1978 an estimated 6,200 rainbow smelt died during a three-week period in December from impingement episodes at the facility. At the time, a group of state, federal, university and facility personnel met regularly to address potential impacts from the facility. Concern was expressed by these biologists that impingement events from Pilgrim could be significantly affecting the Jones River smelt population. This prompted DMF to conduct an intensive, three-year (1978-1981) study (see Lawton, et al., 1990) to develop an estimate of the adult rainbow smelt population size in the Jones River so that an assessment of the plant's effects could be evaluated.

Results of the Lawton, et al., study state that, based on an estimate of egg production, an unbiased sex ratio, and age-specific fecundity, rainbow smelt spawning stock abundance was estimated to be 4,180,000 adults in 1981. The 6,200-fish loss due to impingement was projected to have reduced the Jones River spawning population by less than one percent, and was not considered to have a significant, negative effect on that population.

Based on a recent interview with personnel at the Division of Marine Fisheries, there have been no recent quantitative estimates of the adult rainbow smelt population in the Jones River. However, judging from visual information on both egg density and adult movement, Brad Chase, DMF (pers. comm. to G. Szal, August 29, 2005) estimates that there has been a sharp decline in the rainbow smelt population in the Jones River since the time when the Lawton, et al. (1990), studies were conducted. Unfortunately, without a quantitative evaluation of the rainbow smelt population size in the Jones river, Mr. Chase felt it was not possible to assess the potential impact of Pilgrim's impingement events on the Jones River smelt population.

Entrainment

Effects to winter flounder:
Organisms entrained at power plants are typically subjected to a number of stresses including mechanical stress, stress from pressure drop and stress from rapid heating (delta temperature effects). Winter flounder are the primary species of concern at many facilities along coastal Massachusetts due to their intrinsic economic value and recent population decreases. The Pilgrim Nuclear facility employs several methods of evaluating the impact of the intake on the local winter flounder population adjacent to the facility. The first is the "equivalent adult" method in which the estimated number of eggs and larvae entrained (and assumed killed) by the facility are theoretically "grown up" into adults of different age categories based on literature reports on percent survival from one life stage to the next in wild populations. The number of equivalent adults of a particular adult age (e.g., 3-year olds) can be compared with the number of actual adults, of many year classes, found per square mile in areas adjacent to the facility to form an index of impact.

Density of adult winter flounder was assessed primarily in Plymouth/Kingston/Duxbury Bay (PKDB) and adjacent waters, as these areas were thought to be the primary spawning ground that produced the larvae and eggs entrained by the facility. Researchers conducted sampling in this area using a commercial "otter trawl", a device used to capture bottom fish. The number of equivalent adults cropped by the facility divided by the mean number of flounder found per square mile of PKDB and adjacent areas was used to provide a rough idea of the effect of the facility's impacts due to entrainment of winter flounder.

There are a number of difficulties to be overcome if one is to use this approach. First there are issues encountered in sampling both the adult population in the field as well as the egg and larval population entrained. For example, researchers conducting this work have assumed an otter trawl efficiency of 50%, but the actual efficiency may be much lower (or higher), which would alter the number of fish in the study area per square mile and the apparent impact. Second, entrainment sampling results, in addition, are quite variable. Third, it is difficult to determine the accuracy, and therefore, the applicability, of the survival matrix used in estimating equivalent adults.

Three age-specific survival matrices were provided by Entergy Nuclear (Environmental Protection Group 2005). One matrix uses un-staged larval information (i.e., all larvae are considered to be the same age); the other two use survival data from one stage to the next for four different larval life stages. Because staged larval survival data should provide a greater degree of accuracy, we discarded the un-staged information for this review. Of the two remaining matrices, we chose that provided by Gibson (1993) which was used to evaluate winter flounder issues in Mt. Hope Bay.

A fourth difficulty in estimating impact is choosing a particular adult age class for equivalent adults entrained. We assume (see below) that the number of Age-4 equivalent adults entrained is proper for comparison to the estimate of the number of adults (all ages) per square mile found in the study area. Many winter flounder are fully mature at Age-3, but some are not (pers. comm. Robert Lawton, MADMF to Gerald Szal, MADEP). We used Age-4 because almost all winter flounder in the Cape-Cod Bay area are mature at Age-4 (pers. comm. R. Lawton to G. Szal). A more accurate estimate of impact could be prepared if a matrix of length-age-survival data were available for the field population.

The following table provides estimates of entrainment impacts at the Pilgrim Nuclear Power Plant facility in Plymouth, MA, on the local winter flounder population. Estimates are based on data in Environmental Protection Group (2005).

Table 2

Year	No. Adult Winter Flounder in study area[1]	No. Adult Winter Flounder per square mile[2]	Estimate age-3 adults entrained[3]	Estimate age-4 adults entrained[4]	Square miles age-4 adults lost to entrainment[5]
1995	212,989	2,063	9,703	5,919	2.9
1996	316,986	3,070	15,401	9,395	3.1
1997	313,959	3,041	47,091	28,726	9.4
1998	264,812	2,565	77,394	47,210	18.4
1999	176,271	1,707	2,383	1,454	0.9
2000	464,176	4,496	4,521	2,758	0.6
2001	400,812	3,882	33,626	20,512	5.3
2002	476,263	4,613	19,703	12,019	2.6
2003	262,604	2,544	2,951	1,800	0.7
2004	157,532	1,526	50,851	31,019	20.3

Footnotes:

1. Adults were those fish that were $\geq$ 280 mm in total length (taken from Table 1, pg. 8 of the Environmental Protection Group, 2005 report).
2. The size of the study area changed over the course of the evaluations. According to J. Scheffer (Pilgrim) all estimates in this column are corrected to the same study area size. They have been based on the area swept by the otter trawl used to capture winter flounder and a trawl efficiency of 50%. The current (2004) size of the study area is about 103 square miles.
3. The equivalent adult method of estimating how many adult of age 3-years would have resulted from the eggs and larvae entrained by the facility, based on literature growth and survival data, was used to obtain these figures. Age-3 adult data were taken directly from Entergy Nuclear, 2005 (Table 5, pg. 86); literature data used to calculate survival from one stage to the next was that from Gibson, 1993, as reported by Entergy Nuclear, 2005.
4. Age-4 adult numbers were estimated based on a survival of 0.61 (pers. comm., Robert Lawton, MADMF to Gerald Szal, MADEP, 2/6/2001) from Age-3 to Age-4.
5. Calculated as: (Age-4 adults entrained)/(No. winter flounder per square mile). Because the study area is about 100 square miles (actually 103), these figures are approximately equivalent to the percentage loss to the population in the study area.

Entrainment loss as square miles of adult flounder, using Age-4 equivalent adults entrained, ranged from 0.6 to 20.3 square miles over the 10 years of evaluations. Because the study area was approximately 100 square miles in size, the square mile losses in this last column approximate a percentile loss to the population at large, although the caveats mentioned above should be kept in mind when viewing these estimates. Whether or not these levels of impact are a "significant" detriment to the population, and will result in slowing the return of much higher population densities, is currently not known. In addition, to the author's knowledge, a policy statement regarding losses on a square mile basis has not been issued by any of the state or federal agencies involved with this project. EPA Region 1 has stated in the past that population impacts of 5% or greater are typically of concern, but, to the author's knowledge, the bounds of this particular population have not been agreed upon by state or federal agencies.

A second method of evaluating entrainment impact to winter flounder used by the facility was to estimate the percentage of the total larval population passing in front of the facility that is entrained. Estimates of percent entrainment were very low: less than 1%.

The third method used by the facility to evaluate impact was the RAMAS (Risk Analysis Management Alternative System; Ferson, 1993) winter flounder model. It was used from 1999-2001 to further evaluate the effects of the facility on the Cape Cod Bay winter flounder population. Results suggested that stock reductions from 2.3 to 5.2% might occur as the direct result of entrainment at the facility.

Effects to other finfish species:
Several species, besides winter flounder, suffer substantial entrainment losses at the Pilgrim facility. These are cunner, mackerel, menhaden and atlantic herring. Numbers of equivalent adults (of different ages) estimated by the facility to have been lost due to entrainment effects are listed in Table 3. Numerical values in this table are estimates of the equivalent numbers of adult fish (age) entrained by Pilgrim over the past 11 years (based on data in Environmental Protection Group, 2005). Note that Atlantic herring figures are for entrainment/impingement combined and could not be separated due to the manner in which they were reported.

Table 3

Year	Cunner (1)	Mackerel (3)	Menhaden (2)	Atlantic herring (3)
1994	174,726	830	732	10,774
1995	525,573	6,245	2,452	25, 518
1996	313,002	3,526	1,781	6,096
1997	465,986	942	10,531	16,091
1998	1,542,772	1,824	7,564	2,697
1999	332,601	60	4,072	7,518
2000	319,247	1,216	178	8,120
2001	473,361	311	349	2,701
2002	101,668	482	1,382	2,425
2003	82,467	514	1,187	699
2004	188,107	304	50	3,169

Screenwash and Fish-Return System:

Intake screen wash: The cooling water intake bay at Pilgrim has a number of fine-mesh screens within it that are used to keep fish (but not most fish larvae and eggs) from being entrained into the facility. Fish impinged upon these screens can suffer negative acute or chronic effects. At Pilgrim, impinged fish are knocked off the screens by a salt-water spray system. Under normal operation, screens are rotated only once per 8-hour shift. At the end of the shift, the screens are rotated, and the spray system is operated to dislodge fish from the screens. These fish are shunted to a holding tank where they are counted and further shunted to the intake embayment about 100 yards upstream of the intake. To the author's knowledge no studies have been done to evaluate re-impingement rates. Although large-scale impingement events (>100,000 fish) have taken place at the facility, most of these have been with young-of-the year.

If the number of fish during one of the 8-hour screen-rotation periods exceeds 160 fish (a rate of 20 fish/hour) an "impingement event" is declared. During such an event, the screens are put into constant rotation, and the event is monitored (i.e., fish are counted) until the event is over. The event is reported as soon as possible after it begins and information on species involved, life stages and numbers of fish is related to the permitting authorities and the Massachusetts Division of Marine Fisheries.

The pressure-wash spray system has two sets of nozzles. The first to come in contact with impinged fish is a low-pressure wash (20 pounds per square inch [psi] or less) which is used to remove most fish from the intake screens. The second is a high-pressure wash (80-100 psi) which removes any remaining fish and/or debris. Water for the spray wash is drawn from the saltwater service system and is de-chlorinated prior to use. Reasons for chlorinating this system are explained below.

There are five salt service water pumps at Pilgrim, each with a capacity of 2,500 gallons per minute. The salt service water system has two purposes. It is used to supply cooling water to a number of components within the plant, but is also used for emergency cooling. Typically, four pumps are kept running and the other is kept in reserve. Because the salt water service system must constantly be available for emergency cooling, chlorine alone is used to prevent biofouling within the system. Thermal backwashing (see below), a method used to control biofouling in the intake bays, is not allowed by the Federal Nuclear Regulatory Commission within this system because the water in the salt water service system must constantly be kept cool. The target concentration for chlorine within this system is 0.25 mg/L but the system concentration may reach 1.0 mg/L. Water for this system is taken from the intake bay; chlorinated water from this system is released through the 010 discharge into the primary discharge canal (discharge number 001). Because the 001 discharge is so large (310,000 gpm), the chlorine concentration (after mixing) in the discharge canal due to the 010 release should not reach levels that are above water quality standards.

Discharge Effects

Cooling water discharge:

The Pilgrim Nuclear facility's discharge is located in an open-coastal environment and is well situated for rapid mixing of its heated discharge. Effects of the heated discharge on finfish, benthos and Irish Moss were studied for more than twenty years. Primary impacts include at least two well-documented events of gas-bubble disease in finfish in the 1970s. Since that time, to the author's knowledge, no other major events appear to have taken place. In addition, due to effects on Irish Moss, the facility reimbursed one harvester for losses. Effects of the discharge on the benthic community appear to be primarily limited to scouring. Judging from diver-assisted studies conducted in the late 1990s, it appears that no more than 1-2 acres of the benthic community were negatively affected by the plant's discharge.

Thermal backwash:

About four to five times a year, for a period of about 1.5 to 2 hours, heated water from the downstream end of the steam condensers is re-routed back through the system and out through the intake embayment. This is done to control macro-fouling, primarily from mussels. To accomplish this, the facility shuts down one of the two intake pumps and pushes hot water back through half the system. During this period (about 34-45 minutes) the water within the half of the system receiving the backwash is typically heated to between 105°F and 110°F, but may reach as high as 120°F. The second half of the system is treated in the same manner. Because the facility has to reduce load during these times, which is expensive, the duration and number of backwashes per year is kept to a minimum.

In summary, during a thermal backwash, about 155,000 gpm of heated water (>105°F) is sent into the intake embayment for a period of about 1.5-2 hrs. Studies to evaluate potential impacts of the thermal backwash have not been performed to the knowledge of the author.

Recommendations to minimize impacts from Pilgrim:

1. The resource agencies in concert with the permit agencies should consider further evaluation of the intake effects to winter flounder. If effects are found to be substantial, these agencies should determine what steps need to be taken to reduce the impacts of the facility on the winter flounder population.

2. Because impinged fish from the intake screens are shunted back into the intake, there is a concern that these fish, weakened from impingement, will simply be re-impinged. An assessment of re-impingement rates, especially during large-scale events, should be considered by the permitting and resource agencies. These studies should also include an evaluation of the best point for locating the screen-wash discharge such that it would have the smallest negative impact on the populations of impinged species.

Literature Cited

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