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The Northeast Utilities System

October 20, 1994
D08071

Mr. Timothy Keeney, Commissioner
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

References:
1. Letter (D02278), E.J. Mroczka to L. Carothers, dated October 28, 1988
2. Letter (D03141), E.J. Mroczka to L. Carothers, dated October 31, 1989
3. Letter (D04143), E.J. Mroczka to L. Carothers, dated October 30, 1990
4. Letter (D05008), J.F. Opeka to T. Keeney, dated October 29, 1991
5. Letter (D05905), J.F. Opeka to T. Keeney, dated October 29, 1992
6. Letter (D06995), C.F. Sears to T. Keeney, dated October 21, 1993

Dear Commissioner Keeney:

Millstone Nuclear Power Station
Ecological Monitoring Program

Northeast Utilities Service Company (NUSCO), as agent for Northeast Nuclear Energy Company (NNECO), during October of the previous six years has presented to the Connecticut Department of Environmental Protection (DEP) an update on the status of the Millstone Nuclear Power Station (MNPS) fish return sluiceways (References 1 through 6). Attached is the Progress Report on the MNPS Fish Return System (Enclosure 1). It includes the results of a one-year study to determine the effectiveness of the MNPS Unit 3 Fish Return System as well as a summary of the number of days the MNPS Unit 1 Fish Return System has been out of service.

Over 90% of the organisms impinged at Unit 3 were returned to Long Island Sound via the fish return sluiceway and survival of most organisms returned was high, especially for demersal fish and crustaceans. No further studies of impingement at MNPS are presently planned. The MNPS Unit 1 fish return sluiceway may be taken out of service for relatively short periods due to high debris loads and subsequent re-impingement of returned material. The number of days the Unit 1 fish return was taken out of service in 1993 was 33; future summaries will be reported in forthcoming Annual Reports of Ecological Studies for MNPS. Any unusual impingement events at Unit 2 (more than 300 organisms in a 24-hr period) that occur will be reported to the DEP as per the annual study plan.

If you have any questions after reviewing this submission, please call Milan Keser, NUSCO Environmental Services Division, at (203) 444-4238.

Very truly yours,

Northeast Nuclear Energy Company

D. Miller
Vice President

Enclosure

cc: Mr. Charles Fredette
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Enclosure 1 to Letter No. D08071

PROGRESS REPORT ON THE MNPS FISH RETURN SYSTEMS

MILLSTONE NUCLEAR POWER STATION
NORTHEAST NUCLEAR ENERGY COMPANY
NPDES PERMIT No. CT0003263

Northeast Utilities Service Company
PO Box 270
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October 1994

PROGRESS REPORT ON THE MNPS FISH RETURN SYSTEMS

MILLSTONE NUCLEAR POWER STATION
NORTHEAST NUCLEAR ENERGY COMPANY
NPDES PERMIT No. CT0003263

Prepared by: Christine A. Gauthier

Approved by:____________________
Milan Keser

MNPS UNIT 1 FISH RETURN SLUICEWAY

Under NPDES Permit No. CT0003263, the Connecticut Department of Environmental Protection (DEP) issued DEP Order No. 2859 on July 2, 1980, to the Northeast Nuclear Energy Company (NNECO) to investigate the feasibility of modifying the cooling-water intake systems of Millstone Nuclear Power Station (MNPS) Units 1 and 2 to improve the return of fish and shellfish back to Long Island Sound (LIS). A report (NUSCO 1981) was submitted to the DEP on July 31, 1981, which demonstrated that backfitting a fish return sluiceway at MNPS Unit 1 was a prudent alternative. With the concurrence of the DEP, the Unit 1 sluiceway was put into operation in mid-December 1983.

A study to examine the mortality of fishes and invertebrates impinged at Unit 1 and returned to LIS via the sluiceway began in January 1984 and continued through July 1985 (NUSCO 1986). Survival of most demersal fish and non-molting crustaceans exceeded 70%. These groups included both winter flounder and American lobster. However, pelagic fishes, including herring, small forage fishes and squids suffered almost complete mortality. The process of impingement alone probably caused most mortalities and the addition of the sluiceway did not increase survival.

NUSCO and DEP agreed (NUSCO 1986) that the Unit 1 sluiceway could be taken out of service during periods of high debris loading that would adversely affect plant operations. The DEP requested accounting of the number of days the sluiceway was out of service.

The number of days that the Unit 1 sluiceway was out of service each month from 1986 through 1993 is included in Table 1. Typically, the sluiceway was taken out of service when mussel removal resulted in high debris loading. As indicated on Table 1, the sluiceway was out of service for 33 days during 1993. This was the smallest number of days the sluiceway has been removed in a 1-year period since 1985.

Table 1. Total number of days when the MNPS Unit 1 sluiceway was not in service.

Month	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	0	0	0	0	2	0	[b]	0[a]	4
February	0	0	0	0	6	0	[b]	0[a]	2
March	0	0	1	0	31	2	[b]	10	7
April	0	0	21	0	15[a]	3[a]	[b][a]	0	0
May	3	8	2	0	31[a]	18	[b][a]	0	0
June	4	1	6[a]	8	6[a]	1[a]	[c][a]	0	0
July	2	6	31[a]	10	3	0	0[a]	0[a]	2
August	8	21	10[a]	3	6	4	15[a]	6[a]	4
September	28	3	4	18	11	3[a]	22	9	5
October	7	5	0	15	0	18[a]	4[a]	4	2
November	30[a]	0	3	3	2	6	4[a]	6	4
December	21[a]	0	0	0	0	8	0[a]	7	3

[a] Unit 1 shutdown.
[b] No information available (NUSCO 1992).
[c] No information June 1-15, 1991, sluiceway in service from June 16-30, 1991.

MNPS UNIT 3 FISH RETURN SLUICEWAY

Introduction

The design of the Millstone Nuclear Power Station (MNPS) Unit 3 intake structure incorporated a system to return fish and invertebrates impinged on the traveling screens back to Long Island Sound. The fish return system consists of fine mesh (0.375-in) screens, fish trays on each screen panel; and low and high pressure nozzles that direct material accumulated on the screens into a sluiceway and a debris trough, respectively. Fish and invertebrates are removed by a low pressure wash and returned to Long Island Sound through the fish sluiceway. To prevent debris recirculation, the material washed into the debris trough is accumulated in a trash hopper and removed. The system was operational when MNPS Unit 3 began commercial generation in April 1986. A 1-yr study of the system in 1986 demonstrated that only 41% of the organisms impinged on the traveling screens were washed into the sluiceway (NUSCO 1988). In response to the study results Connecticut Department of Environmental Protection (DEP) issued and enforcement letter dated February 17, 1988 requiring at least a 70% rate of return sluiceway efficiency and an assessment of improvements.

Over the next year, the fish sprayers were re-angled a number of times in attempts to increase sluiceway efficiency. Return rates ranging from 75-87% were achieved. But along with the increase of fish, the amount of seaweed that exited the sluiceway also increased. Seaweed fouling at Unit 3 caused seven unplanned outages. As a result, from January 1990 through July 1992, six new traveling screens were installed at the intake. Improvements to the traveling screens, fish spray wash system, and debris removal system were completed by the end of 1992. A 1-yr study to determine sluiceway survival and efficiency began in January 1993.

In December 1993, in accordance with Paragraph 5 of NPDES Permit No. CT003263, Northeast Utilities Service company (NUSCO) completed a 1-yr evaluation of the efficiency of the system in separating fish from debris and a study to examine the mortality of returned fishes and invertebrates. This report presents the results of that study.

The Intake Structure and Fish Return System

The Unit 3 intake structure is divided into six bays and contains six circulating, four service water and two screenwash pumps. At full capacity, about 56.6 m^3/sec of water is pumped through the entire structure. Water within each bay passes through a trash rack and a traveling screen. During normal operations, the average water velocity through each bay is 0.24 m/sec. The trash racks in each bay are 4.9-m wide and consist of 1.3-cm thick by 8.9-cm deep vertical steel bars installed 6.4 cm apart at a slope of 5 to 1. The traveling screens, located upstream of the circulating water pumps, consist of an endless band of screening panels 4.3-m wide by 0.61-m high constructed of 9.5-mm mesh copper cloth. The screens automatically rotate when the difference in the water elevation upstream and downstream of any screen reaches 100 mm; rotation can be initiated manually.

After screen rotation begins, screenwash water is directed through the low pressure (10 psi) spray header to flush aquatic organisms out of the fish baskets on the screen panels into the lower fish sluiceway trough, and also through a high pressure (85 psi) spray to clean debris off the screens into an upper trash trough. The 70-cm diameter lower trough exits the west wall of the intake structure and connects to a 30-cm diameter pipe, which runs down along a seawall about 22 m to the north. A 76-cm section of the sluiceway pipe about 30 cm to the west of the intake structure is open to allow for sampling. The sluiceway ends about 10 m from rock rip-rap along the shore. The debris trough exits the intake structure through the east wall and material is removed from the trough by a motorized conveyor system and deposited in a trash hopper for removal offsite.

Materials and Methods

Samples were taken biweekly from January through December 1993, except during the week of September 9, 1993 when no fish were impinged because all six circulating water pumps were inoperatable. Most impingement occurs between dusk and dawn, thus most sampling was done in early morning shortly before or after dawn. Before a sample was collected, the traveling screens were washed to clean them of previously accumulated debris and organisms and then the screens were not allowed to rotate or wash for about 2-3 h. On three occasions, high differential water level due to debris loading caused the screens to run continuously and samples were taken during a 40-min period.

Organisms were simultaneously collected from both the sluiceway and debris troughs. To collect organisms from the sluiceway, a 57-cm long, 6-mm mesh net was attached to a 26-cm diameter metal ring and placed over the end of the sluiceway pipe. Sampling at the end of the sluiceway pipe allowed for a measure of mortality that included impingement, screenwash, and passage through the fish return pipe. The screens were rotated and cleaned and as material accumulated in the sampler during the approximate 40-min wash cycle, the net was emptied about every 5 min. Sampling was continuous during the entire wash cycle as the net was designed to be emptied at the codend while the mouth of the net remained attached to the end of the sluiceway pipe. All organisms were separated from algae and jellyfish by hand and placed into an insulated cooler or bucket containing seawater. During the same time, organisms were counted at the discharge of the debris conveyor system. Live organisms collected from the sluiceway were returned to the laboratory and held in tanks with running seawater for up to 72 hrs. Observations were made at 6 and 24 h following collection and dead organisms were removed. Any specimen with obvious injuries or exhibiting aberrent behavior at the final 72-h observation was classified as dead. Total length of fish, carapace width of crabs, carapace length of lobsters, and mantle length of squid were recorded to the nearest mm. Water temperature at the intake and the laboratory holding tanks were recorded.

Efficiency of the sluiceway system was calculated as a percentage by dividing the number of organisms collected in the sluiceway by the total number of organisms collected in both troughs and multiplying this number by 100. Percent efficiency was calculated by both sampling date and for each species.

Survival estimates were calculated for individual species as well as for groups of organisms classified by body type and season of occurrence based on water temperature. Survival was calculated from the proportion of total numbers of specimens alive at the initial, 6-, 24-, and 72-h observations. Organisms were classified into four body-type groups, which included "pelagic", "demersal", "crustacean" and "squid". Free-swimming fishes (e.g., herrings, silversides, butterfish) were considered pelagic, whereas bottom dwellers (e.g. sculpins, flounders) as well as those with hard integuments (e.g., sticklebacks, pipefish) were classified as demersal. The crustacean group was comprised of crabs and American lobster. The Atlantic long-finned squid was considered as a separate group. For some survival calculations, samples were assigned to three temperature groups: "cold", "cool" and "warm" based on water temperatures at the time of the collection. The water temperatures ranged from 3.5 to 7.0°C (cold), 8.0 to 15.0°C (cool), and 16.0 to 22.0°C (warm).

Results

A total of 24 samples were taken during the study period and 32 species of fish and 11 macroinvertebrates were taken in sluiceway and debris trough collections (Tables 2 and 3). The 952 specimens collected during the study were dominated by 12 species and these comprised 81% of the total: Atlantic long-finned squid (222), Atlantic silverside (160), rock crab (72), Atlantic herring (49), winter flounder (43), spider crab (43), grubby (42), threespine stickleback (41), lady crab (31), butterfish (26), American lobster (26), and mud crab (21).

Table 2. Number of organisms sampled, water temperature and percent efficiency by sample date.

Date	Number Sampled Sluiceway	Number Sampled Debris	Water Temperature (°C)	Efficiency (%)
January 19	115	0	4.5	100
February 2	47	0	1.3	100
February 16	40	0	3.3	100
March 2	15	0	1.6	100
March 16	102	1	1.3	99
March 30	21	0	4.5	100
April 13	28	1	4.9	96
April 27	11	0	6.2	100
May 11	5	0	10.4	100
May 25	32	1	12.5	97
June 7	11	0	13.0	100
June 22	41	2	16.7	96
July 6	52	0	16.9	100
July 20	85	6	18.1	93
August 3	29	1	21.7	97
August 17	62	1	20.5	98
August 31	56	1	21.5	98
September 29	20	3	17.5	87
October 14	24	0	15.1	100
October 26	20	1	14.0	95
November 9	21	1	12.3	95
November 23	51	2	11.0	96
December 7	27	1	10.1	96
December 20	15	1	7.9	94

The numbers of fish and macroinvertebrates collected from the sluiceway trough were compared to the numbers collected from the debris trough to determine the efficiency of the sluiceway. The percent efficiency was calculated for each date (Table 2) for each species (Table 3) and averaged 96% for all specimens collected. Of the 43 species were collected only one, the harvestfish (1 collected in debris trough), had an efficiency of less than 85%. The percent efficiency averaged 96% for fishes and 86% for macroinvertebrates.

Organisms collected from the sluiceway were held in the laboratory for 72 h to determine their survival. In general, demersal fish and crustacean groups had the greatest survival (Table 4). Survival of crustaceans was best in cool water (93%) and lowest in warm water (84%) (Table 5).

Table 3. Species specific efficiency of the Unit 3 Fish Return System in separating fish and invertebrates from debris.

		Numbers Collected		
Species	Common Name	Sluiceway Trough	Debris Trough	Percent Efficiency
Alosa aestivalis	blueback herring	2	0	100
Alosa pseudoharengus	alewife	19	0	100
Anchoa mitchilli	bay anchovy	15	0	100
Brevoortia tyrannus	Atlantic menhaden	16	0	100
Callinectes sapidus	blue crab	4	0	100
Cancer irroratus	rock crab	72	2	97
Carcinus maenus	green crab	12	2	85
Clupea harengus	Atlantic herring	49	0	100
Cyclopterus lumpus	lumpfish	5	0	100
Etropus microstomus	smallmouth flounder	2	0	100
Gasterosteus aculeatus	threespine stickleback	41	6	85
Gasterosteus wheatlandi	blackspotted stickleback	10	0	100
Homarus americanus	American lobster	26	6	80
Libinia spp.	spider crab	43	1	98
Loligo pealei	Atlantic long-finned squid	222	6	97
Lophius americanus	goosefish	3	0	100
Menidia menidia	Atlantic silverside	160	2	99
Merluccius bilinearis	silver hake	3	0	100
Monacanthus hispidus	planehead filefish	1	0	100
Morone americana	white perch	1	0	100
Myoxocephalus aenaeus	grubby	42	0	100
Neopanope texana	mud crab	21	0	100
Ophidion marginatum	striped cusk-eel	4	0	100
Opsanus tau	oyster toadfish	1	0	100
Osmerus mordax	rainbow smelt	1	0	100
Ovalipes ocellatus	lady crab	31	4	89
Pagurus longicarpus	hermit crab	5	0	100
Penaeus aztecus	brown shrimp	5	0	100
Peprilus alepidotus	harvestfish	0	1	0
Peprilus triacanthus	butterfish	26	1	96
Pholis gunnellus	rock gunnel	2	0	100
Pleuronectes americanus	winter flounder	43	1	98
Pomatomus saltatrix	bluefish	1	0	100
Prionotus evolans	striped searobin	4	0	100
Scophthalmus aquosus	windowpane	7	1	86
Selene vomer	lookdown	2	0	100
Sphoeroides maculatus	northern puffer	1	0	100
Syngnathus fuscus	northern pipefish	12	0	100
Tautogolabrus adspersus	cunner	3	0	100
Tautoga onitis	tautog	8	0	100
Urophycis chuss	red hake	2	0	100
Urophycis regia	spotted hake	4	0	100
Total:		919	33	Average % Efficiency: 96%

Table 4. Millstone Unit 3 sluiceway survival by species following various holding periods.

Species	Common Name	Body Type Group[a]	Number Examined	(%) Initial Survival	(%) Survival at 6h	(%) Survival at 24h	(%) Survival at 72h
Alosa aestivalis	blueback herring	P	2	100	0	0	0
Alosa pseudoharengus	alewife	P	19	47	21	0	0
Anchoa mitchilli	bay anchovy	P	15	0	0	0	0
Brevoortia tyrannus	Atlantic menhaden	P	16	50	31	6	0
Callinectes sapidus	blue crab	C	4	100	100	75	75
Cancer irroratus	rock crab	C	72	100	100	98	91
Carcinus maenus	green crab	C	12	82	82	82	82
Clupea harengus	Atlantic herring	P	49	0	0	0	0
Cyclopterus lumpus	lumpfish	D	5	100	100	100	100
Etropus microstomus	smallmouth flounder	D	2	100	100	100	50
Gasterosteus aculeatus	threespine stickleback	D	41	86	86	86	86
Gasterosteus wheatlandi	blackspotted stickleback	D	10	90	90	90	90
Homarus americanus	American lobster	C	26	100	100	100	100
Libinia spp.	spider crab	C	43	100	100	100	89
Loligo pealei	Atlantic long-finned squid	S	222	41	60	20	6
Lophius americanus	goosefish	D	3	33	0	0	0
Menidia menidia	Atlantic silverside	P	160	63	53	30	0
Merluccius bilinearis	silver hake	P	3	33	0	0	0
Monacanthus hispidus	planehead filefish	P	1	100	100	100	100
Morone americana	white perch	P	1	100	100	100	100
Myoxocephalus aenaeus	grubby	D	42	100	100	100	866
Neopanope texana	mud crab	C	21	100	95	95	95
Ophidion marginatum	striped cusk-eel	D	4	75	75	75	50
Opsanus tau	oyster toadfish	D	1	100	100	100	100
Osmerus mordox	rainbow smelt	P	1	0	0	0	0
Ovalipes ocellatus	lady crab	C	31	100	100	87	71
Pagurus longicarpus	hermit crab	C	5	100	100	100	100
Penaeus aztecus	brown shrimp	C	5	80	80	80	80
Peprilus triacanthus	butterfish	P	26	15	8	4	0
Pholis gunnellus	rock gunnel	D	2	100	100	100	100
Pleuronectes americanus	winter flounder	D	43	97	97	94	94
Pomatomus saltatrix	bluefish	P	1	0	0	0	0
Prionotus evolans	striped searobin	D	4	75	75	75	75
Scophthalmus aquosus	windowpane	D	7	100	100	100	83
Selene vomer	lookdown	P	2	0	0	0	0
Sphoeroides maculatus	northern puffer	D	1	100	100	100	100
Syngnathus fuscus	northern pipefish	D	12	92	92	92	92
Tautogolabrus adspersus	cunner	D	3	67	67	67	67
Tautoga onitis	tautog	D	8	100	100	100	87
Urophycis chuss	red hake	P	2	100	100	100	100
Urophycis regia	spotted hake	P	4	50	50	50	50

[a] P=pelagic
D=demersal
C=crustacean
S=squid

Table 5. Percent initial and extended survival for groups (body type and water temperature) of organisms taken in the Millstone Unit 3 sluiceway from January through December 1993.

Body type group	Temperature group	Number examined	Initial survival (%)	Survival at 6 h (%)	Survival at 24 h (%)	Survival at 72 h (%)
crustacean	cold	29	96	93	93	90
	cool	74	97	97	96	93
	warm	102	100	100	95	84
demersal	cold	127	94	94	93	88
	cool	33	94	94	94	88
	warm	9	78	78	78	67
pelagic	cold	140	61	46	23	0
	cool	23	13	9	4	0
	warm	45	4	0	0	0
squid	cool	82	56	41	28	7
	warm	60	22	15	10	5

Survival of crustaceans was similar to the survival of demersal fishes which was highest in cold and cool water (88%) and lowest in warm water (67%) (Table 5). Although more tha half of the pelagic fish and squid survived impingement and sluiceway passage, most died within the 72-h holding period (Table 5).

The eleven most abundant species collected in the study had varying rates of survival, depending on their body type. Over 40% of the Atlantic long-finned squid initially survived impingement , but only 6% survived the 3-d holding period. This species is fragile and in previous studies most did not survive initial impingement and none survived a 72-h holding period. Atlantic silverside, Atlantic herring, and butterfish are all pelagic species and none survived the holding period. However, most of the three abundant demersal fish species survived impingement and had high 3-d survival rates: winter flounder (94%), grubby (86%), and threespine stickleback (86%). All of the five dominant crustaceans had high survival rates, which ranged from 71% for the lady crab to 100% for the American lobster. In general, only crustaceans that were molting when impinged suffered high mortality.

Discussion

The Unit 3 fish return system is a two-trough system. Sluiceway studies conducted in 1986 resulted in poor (41%) return rates and improvements were undertaken to produce at least a 70% rate of return. Intake modifications that took place from 1988 through 1992 improved fish return rates. The new traveling screens increased debris removal capacity three-fold. This improved fish returns because previously fish sprayers were shut-off during periods of heavy loading to prevent recirculation; thus, fish were not washed into the fish return during these periods. New fish spray piping was redesigned to position the fish spray wash directly into the path of the fish buckets. This provided longer spray time and nearly continuous bucket flushing. Plastic fish spray deflectors were replaced with steel and relocated so they were out of the path of damaged fish buckets. Prior to the redesign, some traveling screen panels had buckled and sheered off fish sprayers. Also, some of the older metallic fish buckets corroded and fell off the traveling screens. This problem was resolved by the use of non-metallic attachments to the fish buckets. Following these improvements to the intake the rate of returned of impinged organisms increased from 41% to 96%.

Results of the sluiceway survival study also demonstrated an improvement in the survival of impinged organisms. These finding were conservative in that no control specimens were used to ascertain mortality due to handling and holding in the laboratory. In addition, all injured specimens were considered dead, although some may have recovered if released immediately. Thus, actual survival for most species was probably greater than reported. Survival of most organisms classified as demersal and crustaceans exceeded 80%. These groups include the commercially and recreational important winter flounder and American lobster.

Pelagic fishes, which included mostly herrings and small forage fishes, and squid suffered almost complete mortality. Most of these species were impinged during the summer, when warm water temperatures and concurrent impingement of large masses of jellyfish tend to reduce survival. Many years of impingement data collected at MNPS Unit 1 and 2 indicated that these species rarely survive the impingement process.

The rates of survival found for most species and groups during this study were similar or greater than those reported for the MNPS Unit 1 sluiceway (NUSCO 1986; Table 6). The survival of American lobster, northern pipefish, and cunner was higher at Unit 3 than Unit 1. A high proportion of molting lobsters was collected during the Unit 1 sluiceway study, however, which could have accounted for the difference in the survival rates for that species. At Unit 1, impinged organisms are washed from the screens using a high pressure spray (80 psi), while those at Unit 3 are washed with a low pressure spray (10 psi). As many survival rates were similar, regardless of spray wash pressure, this indicated that the process of impingement on the traveling screens alone may cause much of the mortality.

Results of impingement survival studies at other northeastern Atlantic coastal and estuarine power stations were summarized on Table 7 and compared to the results of this study. Findings were similar, even though sampling methods and plant operations differed among the studies. Survival of fish from MNPS Unit 3 appears to be similar to that found at Brayton Point, Mass. and greater than at Pilgram, Mass. for similar wash cycles. Initial survival for demersal species was similar to that at Oyster Creek, N.J. even though less time elapsed between screen washes there.

Table 6. Comparison of extended percent survival of aquatic organisms returned at Millstone Unit 3 and Unit 1.

Species	Common Name	Percent Extended Survival Unit 3 (1993)	Unit 3 (1986)	Unit 1
Anchoa mitchilli	bay anchovy	0	0	0
Brevoortia tyrannus	Atlantic menhaden	0	0	0
Callinectes sapidus	blue crab	75	100	86
Cancer irroratus	rock crab	91	83	92
Carcinus maenus	green crab	82	77	62
Gasterosteus aculeatus	threespine stickleback	86	72	91
Homarus americanus	American lobster	100	86	38
Libinia spp.	spider crab	89	94	71
Loligo pealei	Atlantic long-finned squid	6	0	0
Menidia menidia	Atlantic silverside	0	0	0
Myoxocephalus aenaeus	grubby	86	97	74
Neopanope texana	mud crab	95	86	100
Ovalipes ocellatus	lady crab	71	90	81
Peprilus triacanthus	butterfish	0	2	0
Pomatomus saltatrix	bluefish	0	0	0
Pseudopleuronectes americanus	winter flounder	94	100	86
Syngnathus fuscus	northern pipefish	92	91	16
Tautogolabrus adspersus	cunner	67	86	20

Conclusion

Improvements to the Unit 3 fish return system more than doubled the percentage of fish returning the Long Island Sound. Removal efficiency exceeded the targeted rate of 70%. Survival of most organisms returned was high, especially for demersal fish and crustaceans. The commercially and recreationally important winter flounder and American lobster both had rates of return greater than 80% and 72-h survival of more than 90%. The improved efficiency of the Unit 3 fish return sluiceway has lessened the impact of impingement on the local aquatic community.

Table 7. Comparison of data from impingement survival studies at other northeastern power stations.

Power Station	Species	Species group[a]	Wash cycle (h)	Holding period (h)	% Survival	Remarks	Reference
Bowline, NY	white perch	P	0[b]	96	56	Not adjusted for	King et al.
	white perch	P	4	96	19	control mortality.	1977
Brayton Point, MA	Atlantic silverside	P	0-8	48	43		LMS 1985
	bay anchovy	P	0-8	48	0		
	northern pipefish	D	0-8	48	94		
	tautog	D	0-8	48	95		
	winter flounder	D	0-8	48	75		
Brayton Point, MA	Atlantic silverside	P	0-8	48	18		LMS 1986
	bay anchovy	P	0-8	48	2		
	cunner	D	0-8	48	75		
	grubby	D	0-8	48	100		
	tautog	D	0-8	48	98		
	winter flounder	D	0-8	48	94		
Danskammer Pt, NY	white perch	P	0	84	40-61	Adjusted for	King et al.
	white perch	P	4	84	9	control mortality	1977
	Atlantic tomcod	D	0	84	83		
	Atlantic tomcod	D	2	84	87		
Oyster Creek, NJ	blueback herring	P	2	none[c]	17		Tatham et al.
	Atlantic herring	P	2	none[c]	8		1977
	bay anchovy	P	2	none[c]	7		
	Atlantic silverside	P	2	none[c]	34		
	northern pipefish	D	2	none[c]	90		
	striped searobin	D	2	none[c]	82		
	smallmouth flounder	D	2	none[c]	74		
	winter flounder	D	2	none[c]	85		
	blue crab	C	2	none[c]	93		
Pilgrim, MA	Atlantic silverside	P	8	56	3	Data combined for	Anderson
	grubby	D	8	56	30	1984-85 studies.	1985a,b
	winter flounder	D	8	56	33		
Pilgrim, MA	Atlantic silverside	P	8	none[c]	77		Anderson 1993
	tautog	D	8	none[c]	87		
	grubby	D	8	none[c]	95		
	winter flounder	D	8	none[c]	88		
Roseton, NY	white perch	P	0	84	29-60	Adjusted for	King et al.
	white perch	P	4	84	23-36	control mortality	1977
	Atlantic tomcod	D	0	84	81		
	Atlantic tomcod	D	2	84	72		

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[a] P indicates pelagic, D demersal, and C crustacean.

[b] 0 indicates continuous wash

[c] Immediate survival estimates given as relatively few specimens held for delayed mortality.

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