New York State Department of Environmental Conservation

The Relationship between Cooling Water Capacity Utilization, Electric Generating Capacity Utilization, and Impingement and Entrainment at New York State Steam Electric Generating Facilities

Technical Document

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July 2010

Citations

This report was prepared by:

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Albany, NY 12233

This report is a New York State Department of Environmental Conservation Technical Document and should be cited in the literature in the following manner:

Nieder, W.C. 2010. *The Relationship between Cooling Water Capacity Utilization, Electric Generating Capacity Utilization, and Impingement and Entrainment at New York State Steam Electric Generating Facilities*. New York State Department of Environmental Conservation Technical Document. Albany, NY. July 2010.

Abstract

Throughout New York State, many industrial facilities operate cooling water intake structures and use large volumes of surface waters for cooling machinery or for condensing steam. The steam electric generating industry uses the largest percentage of this cooling water: up to 17 billion gallons per day. The federal Clean Water Act (CWA) and 6 NYCRR § 704.5 requires that the location, design, construction and capacity of cooling water intake structures reflect the "best technology available" (BTA) to minimize adverse environmental impact (*i.e.,* impingement and entrainment). Understanding the relationship between cooling water use, electric generation and the associated adverse environmental impact is critical to determining how this impact can be minimized by managing flow and generation at a facility.

The purpose of this study was to evaluate the relationship between electric generating capacity utilization, cooling water capacity utilization and adverse environmental impact through the analysis of recent data (*e.g.*, cooling water use, generating capacity utilization, entrainment and impingement) collected from several steam electric generating stations in New York State. Results of these analyses indicate that non-targeted reductions in cooling water capacity utilization may have little effect on reducing the adverse environmental impact caused by the operation of cooling water intake structures in New York State. There is also no predictable relationship between electric generating capacity utilization and cooling water capacity utilization indicating that the cooling water systems at many facilities in New York are operated more often than necessary to condense steam.

The seasonal dimension of both energy demand and fish reproductive and migratory life history may be the driving factors influencing entrainment and impingement at a facility. Most steam electric facilities in New York operate under peaking and load-following conditions but they still have a disproportionately large adverse environmental impact on the resource. This finding contradicts assumptions that peaking facilities tend to operate during the times of the year when biological activity would be low and use a proportionately lower amount of cooling water than baseloaded facilities. The results of this study also demonstrate that it is critical for the relationship between electric generating capacity utilization, cooling water capacity utilization, and the resulting impact to be evaluated carefully at a facility before determining if and how any restrictions should be placed on a facility's electric generation or cooling water use to meet the requirements of CWA § 316(b) and 6 NYCRR § 704.5. This study also demonstrated that using design flow in the establishment of baseline conditions at an existing facility provides the appropriate benchmark to measure the effectiveness of technology and operational measures in reducing the adverse environmental impact from a cooling water intake structure.

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Introduction

The U.S. Geological Survey recently estimated that approximately 200 billion gallons per day, or 60 percent of the total amount of surface waters withdrawn daily for use in the United States, is used by the steam electric industry for condenser cooling (Kenny *et al.* 2009). Throughout New York State, many industrial facilities use large volumes of surface waters to provide for the cooling of machinery or for condensing steam, with the steam electric generating industry by far using the largest percentage: up to 17 billion gallons per day. Nearly half of the steam electric generating facilities in the United States use a once-through cooling system (Veil 2000) to condense steam generated to drive turbines. A generating facility operating a once-through cooling water system withdraws water from a waterbody, passes the water through steam condensers or other structures to absorb waste heat, and returns the water to the water body at a higher temperature (*i.e.,*thermal discharge).

Though a non-consumptive use (virtually all of the water used by the steam electric industry is returned to the water body), the use of the surface waters for cooling has an adverse environmental impact on aquatic resources. At the cooling water intake side, aquatic organisms are either entrained or impinged. Entrainment occurs when small organisms such as ichthyoplankton and zooplankton pass through screens designed to keep larger material out of the cooling system, travel through the facility and are returned to the waterbody in the heated effluent. Depending on maximum discharge temperatures, changes in water temperatures, biocide use, and mechanical effects (abrasion, pressure changes, and shear forces), a large proportion of these entrained organisms may be returned to the waterbody injured or dead (EPA 2004, EPRI 2000, Cannon *et al.* 1978). Impingement is a process whereby aquatic organisms that cannot fit through the screens become trapped on the screens, and depending on the species of organism, the design of the screens, and whether or not the organisms are quickly removed from the screens and returned to the waterbody, a large number of these organisms may also die (EPRI 2005, EPRI 2003a). The other impact from using a once-through cooling system is caused by the thermal effluent but that is beyond the scope of this paper.

Since 1972, the federal Clean Water Act (CWA) has required that the location, design, construction and capacity of cooling water intake structures (CWIS) reflect the "best technology available" (BTA) to minimize adverse environmental impact[1] [*see* CWA § 316(b) and 6 NYCRR § 704.5]. This requirement recognizes four major features of a cooling water intake structure that influence the nature and degree of adverse environmental impact caused by its operation: the location, design, construction, and capacity. Much attention and research has gone into determining the influence of the location, design, and construction of the intake, and several technologies have been developed to reduce impact based on this research and technology development (EPA 2003). The influence of capacity (both flow and electric generation) on the overall adverse environmental impact is less well understood and is based on the relatively untested assumption that there is a direct, proportional relationship between capacity utilization and adverse impact. In fact, the Electric Power Research Institute (EPRI) did not find a consistent relationship between the volume of water withdrawn and the number of fish entrained by power plants in the United States and found the relationship to be highly variable, indicating that further study on the influence of capacity utilization is warranted (EPRI 2003b).

Inadequate consideration has been given to the relationship between seasonal swings in ichthyoplankton abundance timed with seasonal electric generation requirements. This relationship can result in a facility having a large adverse environmental impact even though it may not operate (*e.g.*, generate electricity) for much of the year. Understanding the relationship between cooling water use, electric generation and the associated adverse environmental impact is critical to determining how this impact can be minimized by managing flow and generation at a facility. The New York State Department of Environmental Conservation (DEC) and Hudson River based utility owners have long understood this relationship on the Hudson River and have used this understanding to reduce entrainment at some facilities (EPRI 2003b, Consolidated Edison 1986 & 1984).

EPRI (2003b) did find a general relationship between the number of organisms entrained and the volume of water withdrawn for power plants in the northeast indicating that a reduction in cooling water use will reduce the entrainment of fish to some extent. A similar, though weak, relationship was found with the impingement of threadfin shad and volume of flow at power plants in the southeastern United States (Loar *et al.* 1978). In the CWA § 316(b) Phase II Rule

[1] Adverse environmental impact is defined as the number of fish killed or injured by the cooling water intake system. *See* Final Rule, 66 Fed. Reg. at 65,262-65,292; and *Riverkeeper, Inc. v. EPA*, 358 F.3d 174 (2d. Cir. 2004).

promulgated in 2004, the EPA stated that entrainment at a site is generally proportional to flow, and facilities operating only during peak demand periods do so during periods of low biological activity and use significantly less water than facilities operating at or near full generating capacity. This statement would indicate that there is a well understood and predictable relationship between generating capacity utilization, cooling water use, and aquatic impact reduction. Consequently, the EPA "determined that it was n[ot] necessary …. for these facilities [*e.g.*, facilities that utilized less than 15 percent of their generating capacity] to reduce entrainment where the total volume of water withdrawn and the number of organisms that would be protected from entrainment is likely to be small." (EPA 2004). This variance was based on the assumption that by reducing the percent of electric generating capacity utilized at a facility, there would be a reduction in the volume of cooling water used leading to a minimization of the impingement and entrainment of aquatic organisms. In order for this generalization to be verified in New York State, it must be demonstrated that: (1) there is a proportional relationship between the percent electric generating capacity utilization and percent cooling water capacity utilization for the steam electric industry; and (2) there is a proportional reduction in entrainment and impingement corresponding to a percent reduction in generating capacity utilization.

Related to this issue is the consideration of CWIS capacity when estimating calculation baseline impact. New York State has established a "calculation baseline" to assess the relative reductions in entrainment and impingement possible at existing industrial facilities (such as steam electric generating plants) that utilize once through non-contact cooling water systems. The calculation baseline is defined as:

> *An estimate of impingement mortality and entrainment that would occur at a facility assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh conventional traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody and is operated at the full rated capacity 24 hours a day, 365 days a year. This is the baseline of adverse environmental impact to be used in estimating reductions in impingement mortality and entrainment resulting from implementing "best technology available".*

This definition is based on EPA regulatory documents and previous New York State administrative proceedings[2]. The foremost reason for using a calculation baseline is to establish a benchmark, or baseline, of the maximum potential adverse environmental impact that can be caused by the operation of an existing cooling water intake structure. Once this baseline is established, it is then possible to evaluate the effectiveness of implementing different technologies and operational measures at a facility to minimize the adverse environmental impact to meet the best technology available, or BTA, requirement of CWA § 316(b) and 6 NYCRR § 704.5. Flow (in this case cooling water capacity utilization) is clearly an important variable in estimating potential and actual adverse environmental impact. What is not as straight forward is the degree to which simple, non-targeted reductions in CWIS capacity utilization from baseline reduce this impact.

The purpose of this report is to evaluate the relationship between cooling water capacity utilization at existing power plants and adverse environmental impact through the analysis of recent data collected by the DEC from several steam electric generating stations in New York State. The DEC is in a unique position to undertake such an analysis given the decades of research that New York State has conducted with the power generation industry to develop and test technologies designed to reduce, and in some cases minimize, the adverse environmental impact caused by CWISs (EPA 2003, McLaren and Tuttle 2000, Ross et al. 1993 & 1996, Fletcher 1990). In addition, there are a large number of steam electric generating facilities in operation across New York State. New York also has an extensive record of research with the steam electric power industry on the Hudson River addressing how managing cooling water use can be used to substantially reduce entrainment (EPRI 2003b, Englert *et al.* 1988; Consolidated Edison 1984&1986). This has lead to the reduction in the entrainment of fish by managing the volume of cooling water used at some Hudson River power plants during times of the year when fish species would be most vulnerable.

This report presents the results of analyzing cooling water use, electric generation capacity use, impingement, and entrainment data recently collected from nineteen (19) steam electric generating facilities in New York State in order to test the assumptions that:

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[2] Matter of Dynegy Northeast Generation, Inc., on behalf of Dynegy Danskammer, LLC, Decision of the Deputy Commissioner, May 24, 2006 [2006 WL 1488863 (N.Y.Dept.Env.Conserv.)]; Riverkeeper, Inc. v Johnson, 52 AD3d 1072 (3d Dept. 2008), appeal denied 11 NY3d 716 (2009).

1. There is a direct, proportional relationship between generating capacity utilization, cooling water capacity utilization, and the impingement and entrainment of aquatic organisms; and
2. Simply reducing cooling water use from full-design flow results in proportional reductions in adverse environmental impact.

Methods

Nineteen steam electric facilities located across New York State were included in this study. See Tables 1 and 2 for facility names, specifications and other facts. For each facility, up to five metrics were calculated or estimated depending on the available data:

1. The cooling water design capacity in million gallons of water per day (MGD).
2. The annual average cooling water use per year (in MGD) was either obtained directly from the facility owner or from the compliance records maintained by the DEC.
3. The plate rate electric generating capacity (in MWhr per year) was obtained either directly from the facility owner or from the annual *Load and Capacity Data "Gold Book"* produced by the New York Independent Systems Operator (NYISO).
4. The actual annual generating capacity utilization of the facilities was either obtained directly from the facility owner or from the 2008 NYISO *Gold Book.*
5. Baseline and actual impingement and entrainment data came from several consultant reports that were provided to the DEC by the facility owners (see Reference Section for listing of reports). The year(s) entrainment and impingement data that were collected are presented in Table 2. Most of these studies were conducted within the last decade.

Comparisons among the facilities using the actual water use in MGD and numbers of fish impinged and entrained resulted in non-significant, weakly correlated relationships between the cooling water use and adverse environmental impact ($0.005 \leq R^2 \leq 0.14$; $p>0.05$). Therefore, all comparisons and analyses were done using the percent reductions from design capacity operation and not on the actual energy generated (MWhr), cooling water volume used, or numbers of fish impinged and entrained. This was done primarily to determine the influence of "capacity utilization" on reducing adverse environmental impact. This also allowed the determination of impact reductions due to operational practices at facilities across the state. Given the variability in facility size and efficiency, and the abundance and diversity of the fish community in the diverse aquatic ecosystems throughout New York, comparing the results using a percentage scale provided a common currency that could be applied across facilities and water bodies thereby increasing the power of the analyses.

Table 1: Generating capacity and non-contact cooling water capacity at major industrial facilities in New York State (MW = megawatts; MGD = million gallons per day).   The steam electric facilities in "bold & italicized" were included in the analysis in this report.

Facility	Owner	Waterbody	MW	MGD
AES Cayuga	AES	Cayuga Lake	306	219
AES Greenidge	AES	Seneca Lake	161	113
AES Somerset	AES	Lake Ontario	675	279
AES Westover	AES	Susquehana River	146	102
Arthur Kill	NRG Energy	Arthur Kill	842	713
Astoria Generating	Astoria Generating	East River	1,290	1,254
Barrett (E.F.)	National Grid	Barnum's Cove	384	294
Black River Power	Black River Power	Black River	50	55
Bowline 1&2	Mirant	Hudson River	1,139	912
Brooklyn Navy Yard	Brooklyn Navy Yard	East River	286	55
Danskammer	Dynegy Northeast	Hudson River	491	457
Dunkirk Steam Station	NRG Energy	Lake Erie	600	579
East River Generating	ConEd	East River	317	369
Far Rockaway	National Grid	Jamaica Bay	109	84
Fitzpatrick	Entergy	Lake Ontario	825	596
Ginna	Rochester Gas & Electric	Lake Ontario	496	490
Glenwood	National Grid	Hempstead Harbor	210	179
Huntley	NRG Energy	Niagara River	760	846
Indian Point	Entergy	Hudson River	1,910	2,801
Nine Mile Point 1&2	Constellation	Lake Ontario	1,757	490
Northport	National Grid	LI Sound	1,522	939
Oswego Steam Station	Oswego Harbor Power	Lake Ontario	1,700	1,399
Port Jefferson	National Grid	Pt Jeff. Harbor	385	399
Ravenswood	Trans Canada	East River	2,410	1,391
Roseton	Dynegy Northeast	Hudson River	1,200	926

Table 2: Entrainment and impingement estimates are based on actual cooling water use. Estimates are based on the most recent site-specific data collected (Date). When two dates are indicated, the first date corresponds with entrainment and the second date with impingement. (Note: ND= no data available).

Facility	Owner	Waterbody	Entrainment*	Impingement*
AES Cayuga	AES	Cayuga Lake	576,000	*ND**
AES Greenidge	AES	Seneca Lake	*ND*	29,000
AES Somerset	AES	Lake Ontario	141,469	12,445
AES Westover	AES	Susquehana River	3,900,000	10,200
Arthur Kill	NRG Energy	Arthur Kill	1,548,314,607	4,406,742
Astoria Generating	Astoria Generating	East River	629,832,154	2,916,328
Barrett (E.F.)	National Grid	Barnum's Cove	906,259,233	176,044
Black River Power	Black River Power	Black River	41,000	0
Bowline 1&2	Mirant	Hudson River	127,000,000	30,000
Brooklyn Navy Yard	Brooklyn Navy Yard	East River	38,998,201	0
Danskammer	Dynegy Northeast	Hudson River	161,019,074	144,429
Dunkirk Steam Station	NRG Energy	Lake Erie	47,940,000	62,778,786
East River Generating	ConEd	East River	1,342,191,677	1,500,873
Far Rockaway	National Grid	Jamaica Bay	117,662,685	6,560
Fitzpatrick	Entergy	Lake Ontario	18,004,625	239,357
Ginna	Rochester Gas & Electric	Lake Ontario	28,616,000	35,612
Glenwood	National Grid	Hempstead Harbor	177,879,210	9,562
Huntley	NRG Energy	Niagara River	105,500,000	96,700,000
Indian Point	Entergy	Hudson River	1,200,000,000	1,180,000
Nine Mile Point 1&2	Constellation	Lake Ontario	86,700,000	1,061,900
Northport	National Grid	LI Sound	8,430,808,238	127,118
Oswego Steam Station	Oswego Harbor Power	Lake Ontario	12,824,104	1,246
Port Jefferson	National Grid	Pt Jeff. Harbor	1,014,950,951	76,104
Ravenswood	Trans Canada	East River	199,000,000	82,303
Roseton	Dynegy Northeast	Hudson River	712,000,000	44,096

These data were pooled to provide a statewide analysis of the relationship between cooling water use, electric generation and reductions in impingement mortality and entrainment. Note that not all nineteen facilities were included in all analyses since data for some facilities were either lacking or dated. All data transformations (when necessary) and analyses were performed using Statistica® v 8.0 and Microsoft Excel 2007® and included regression analyses, t-tests and standard descriptive statistics (means, standard deviation, and standard error).

Results and Discussion

Regression analyses were run comparing the reductions in impingement and entrainment to the reduction in cooling water capacity utilization from design (full-flow) capacity (Fig. 1 and 2). Figure 1 displays regression results comparing the reductions in impingement with reduction in cooling water capacity utilization from baseline conditions. The regression is predictably positive but the relationship is surprisingly weak (R^2=0.16) and not significant (*p*=0.14). The fact that this relationship is not significant for New York State facilities demonstrates that there is little direct, proportional relationship between impingement and cooling water capacity use, and that reductions in cooling water capacity use from design capacity are only responsible for 16 percent of the variability in impingement reduction at best. Therefore, 80 percent or more of the variability in impingement reduction is due to other factors such as the location, design, and construction of the cooling water intake structure and the timing of operating the cooling water intake structures in relation to seasonal fluctuations in the abundance of aquatic biota in the waterbody. Given that reductions in impingement in New York are more likely related to variables other than capacity use reductions, and the regression analysis was not significant, no further analysis of impingement was undertaken in this study.

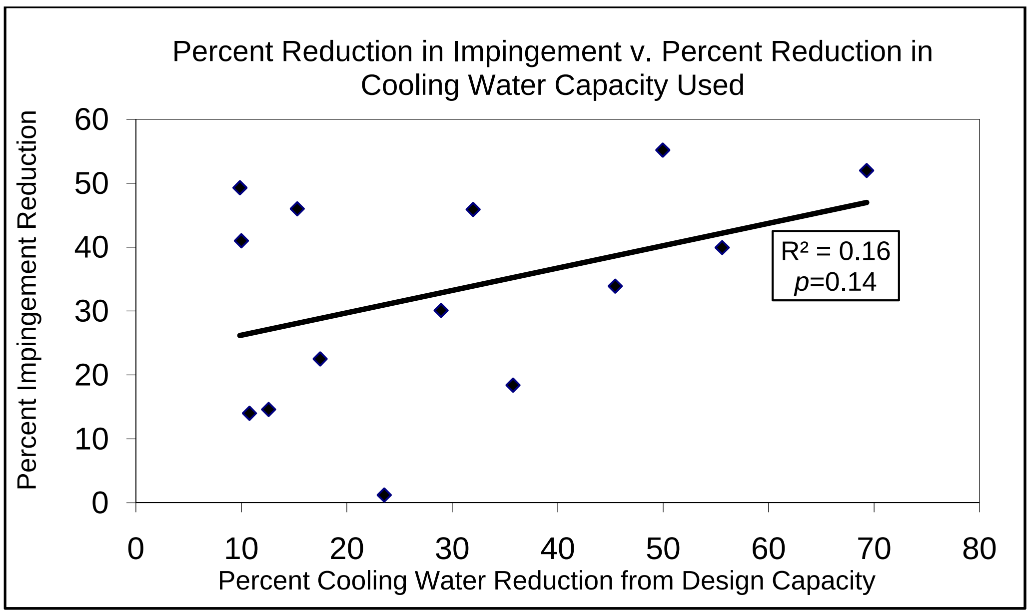

Figure 1: Reductions in impingement from baseline conditions at 14 steam electric facilities in New York State compared with cooling water reductions. The weak relationship is likely due to the effectiveness of traveling screens and fish return systems at some of these facilities in reducing the impingement of many fish species. Seasonality of fish abundance and electric generating demand also likely influence these results.

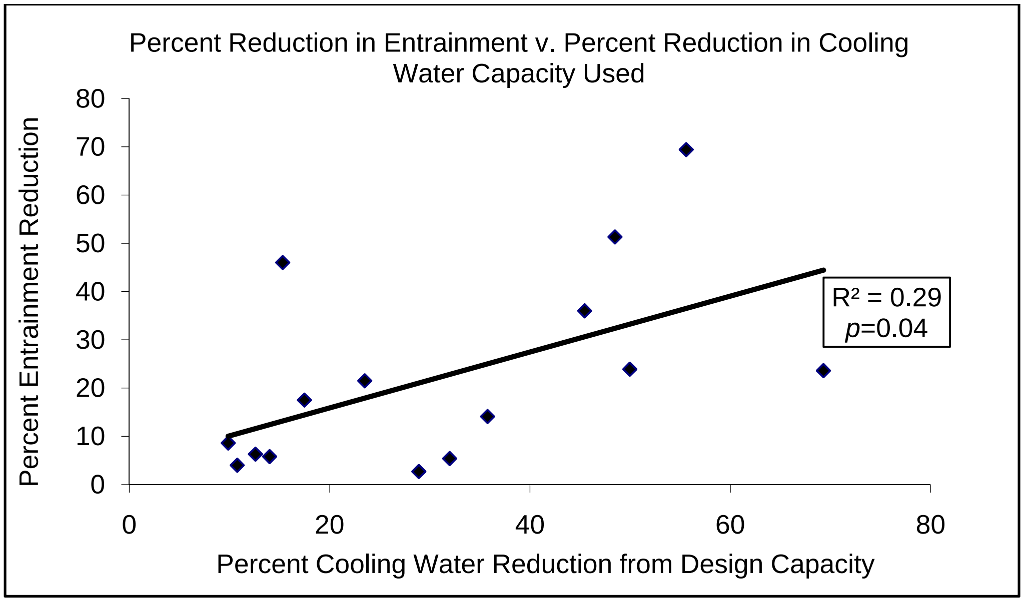

Figure 2: Reductions in entrainment from baseline conditions as a result of reducing cooling water use at 15 steam electric facilities in New York State. Though the relationship is predictably positive, only 29% of the variability can be attributed to reductions in cooling water use. Over 70% of the variability is likely due to the strong seasonality of ichthyoplankton density and energy demand.

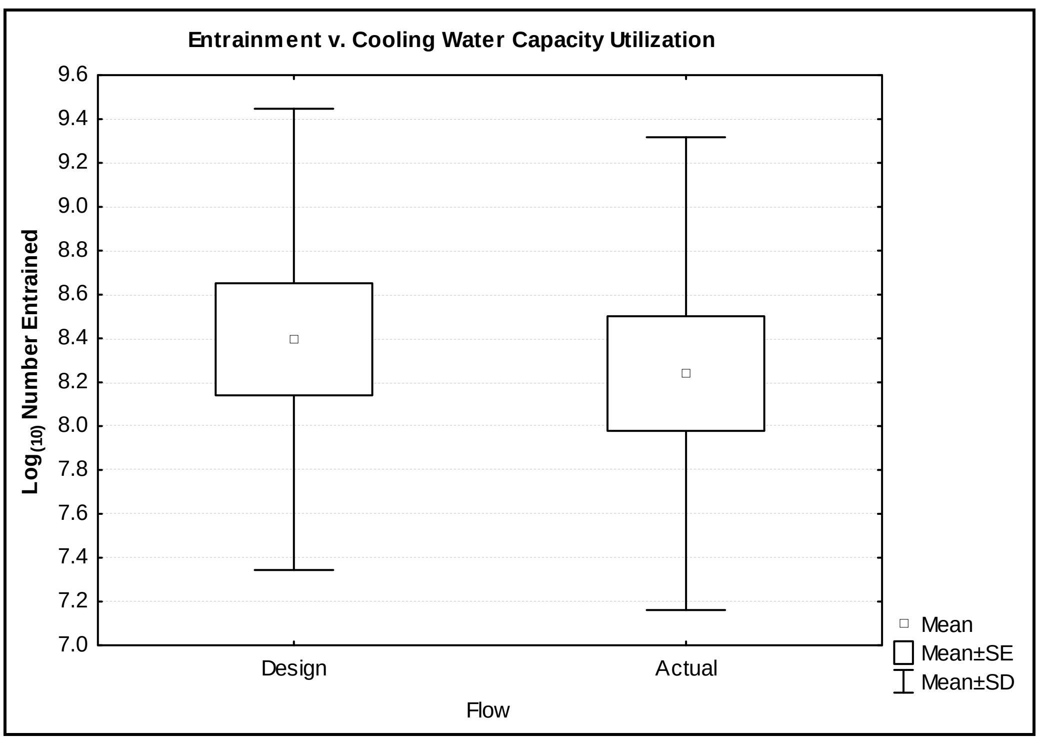

Figure 3: Mean estimated number of fish eggs and larvae entrained (log transformed) at 17 steam electric facilities in New York State at both design capacity and actual capacity utilization of the cooling water intake structure. Though the average entrainment is less at actual operations, this difference was not found to be significant (*p*=0.67).

A regression analysis between the annual mean reduction in cooling water capacity use from design capacity and reductions in entrainment shows a much stronger relationship than shown to exist with impingement, indicating that entrainment at a facility with a CWIS is generally proportional to capacity utilization. However, the results indicate that only about 29 percent of the variability in entrainment reduction is due to reducing capacity use (R^2=29; p=0.04) (Fig. 2). It is not unexpected that this relationship would be stronger than was observed with impingement since the ichthyoplankton susceptible to entrainment are greatly influenced by water currents and intake velocities. However, the average difference in the number of organisms entrained between baseline and actual operating conditions is not significant (p=0.67; Fig. 3). Similar to the results with impingement displayed in Figure 1, much of the variability in the reduction in entrainment, over 70 percent, is due to factors other than reduction in cooling water capacity use. A likely driving factor affecting actual entrainment is the interplay of cooling water use and the seasonality of the life stages susceptible to entrainment. EPRI (2003b) found that the timing of water withdrawal relative to the presence of ichthyoplankton was a confounding factor in trying to determine the level of adverse environmental impact caused by a CWIS. This, coupled with typically higher energy demands during biologically active times of the year, results in a much greater adverse environmental impact than would be predicted based on the annual cooling water capacity utilization alone.

This weak relationship between flow reduction and impact reduction has much to do with how steam electric facilities are operated in New York State. The majority of steam electric facilities in New York are either “peaking facilities” or “load-followers”. Peaking facilities are generally in cold standby for much of the year and are only required to operate during high demand periods –typically during the late spring and summer months. Load-followers operate more frequently than peaking facilities, operating at lower loads earlier in the day and gradually ramping up power levels to match the demand during the day.

Figure 4 displays regression results comparing the reductions in cooling water capacity use to generating capacity utilizations. The regression results show a significant relationship between these two variables (R^2=0.36; p=0.008) which is expected (the less energy produced; the less cooling water used). The more interesting result is the apparent arrangement of facilities into three distinct groups (indicated by “A”, “B”, and “C” in Fig. 4). As it turns out, group “A” make up the baseload facilities that operate in New York (R.E. Ginna, J.A. Fitzpatrick, Indian Point, Somerset, and Dunkirk). This grouping is quite tight, indicating a consistent operational use of cooling water in relation to electric generation (mean water use reduction = 14.8%; STD = 3.1%). Group "C" are the load-following and peaking facilities. The variability in cooling water use to electric generation is much greater than with the baseloaded plants (mean water use reduction = 33.9%; STD = 19.2%). Some of the facilities in group "C" use very little of their electric generating capacity but operate their cooling water system at more than 70 percent of design capacity annually.

The two facilities in Group "B" (Brooklyn Navy Yard and Danskammer), are unique in their use of non-contact cooling water. Brooklyn Navy Yard is a co-generation facility that produces steam for heat for approximately half of the year. During this time of the year, the facility uses significantly less cooling water than a conventional steam electric facility would use. The DEC has required a reduction in cooling water use at the Danskammer facility through the installation and operation of variable speed drive pumps and by requiring fish protective operational outages. This has resulted in a much more efficient use of cooling water and minimizes impacts during biologically active times of the year.

Over the course of a year, peaking and load-following facilities in New York operate at about 20 percent of the designed generating capacity on average (Fig. 5 and 6). The majority of this capacity is utilized during late spring and summer when many fish species spawn resulting in the greatest number of fish eggs and larvae being susceptible to entrainment. An additional complicating factor is that, even though these facilities operate well below 30 percent of the electric generation capacity, they use almost 55 percent of their cooling water capacity on average (Fig. 5). Therefore, a significant reduction in electric generation does not necessarily correspond to a significant reduction in entrainment (Fig. 7). Though peaking and load-following facilities in New York utilized less cooling water capacity than baseloaded facilities on average in 2008, this difference was not statistically significant (p=0.22; Fig. 5).

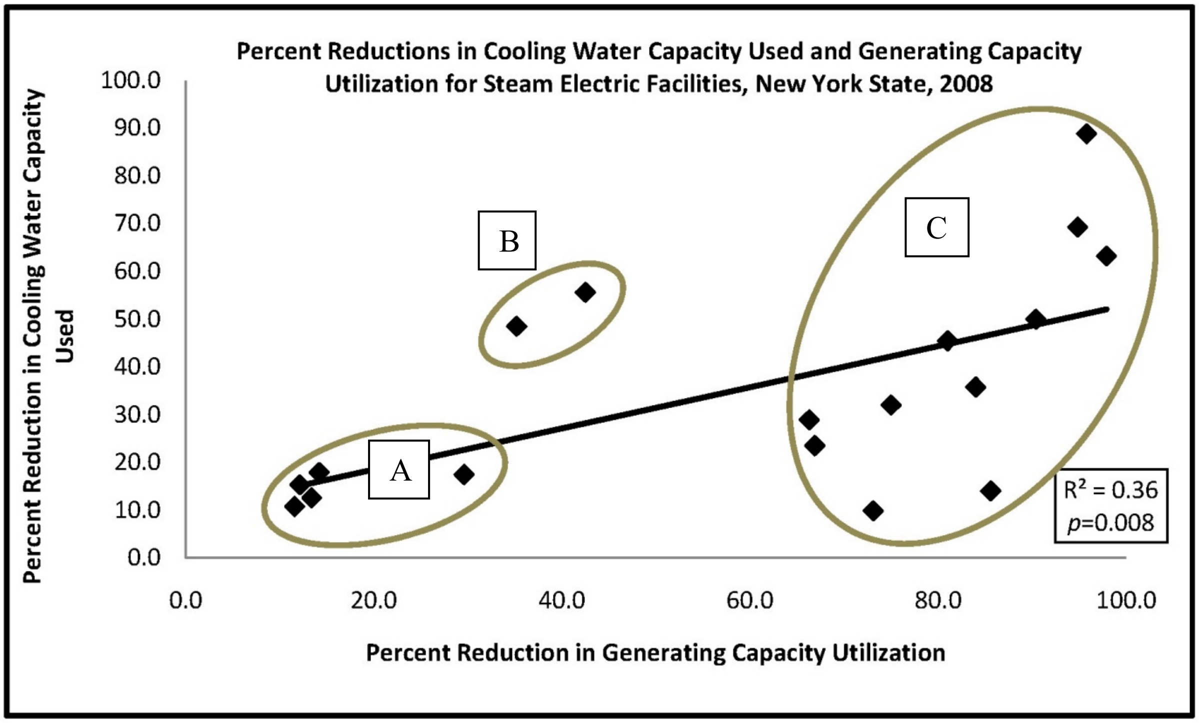

Figure 4: Relationship between the reduction in cooling water capacity used as a function of reducing electric generation at 18 steam electric facilities in New York. The groupings correspond to generating operations (A=baseloaded; B=unique water use; C=peaking and load-following facilities).

A regression analysis comparing the percent reduction in entrainment from baseline conditions to percent reduction in electric generation indicated that there was virtually no relationship between these two variables (R^2=0.04; *p*=0.48) (Fig. 8). This very weak relationship was also negative (r = – 0.20), indicating that the facilities utilizing the least amount of their generating capacity have minimally reduced entrainment from baseline conditions. This is strongly indicative that many of these peaking and load-following facilities operate cooling water pumps in the absence of generating electricity and do so during the most biologically active times of the year. For example, the Port Jefferson Power Station only used 27 percent of its generating capacity in 2008 but operated the cooling water system at about 75 percent of design capacity. This resulted in an estimated entrainment of 91 percent of the baseline conditions. Therefore, a reduction in electric generation capacity utilization of almost 75 percent only resulted in a reduction in entrainment from baseline conditions by 9.0 percent.

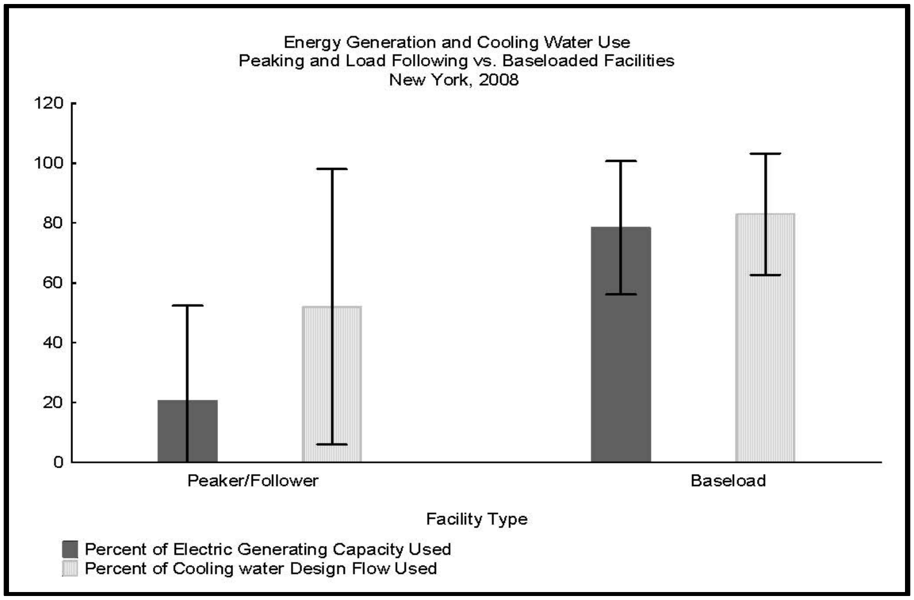

Figure 5: Average electric generating capacity and cooling water capacity utilization at peaking and load-following vs. baseloaded steam electric facilities in New York State during 2008. Error bars represent +/- 2 STD.

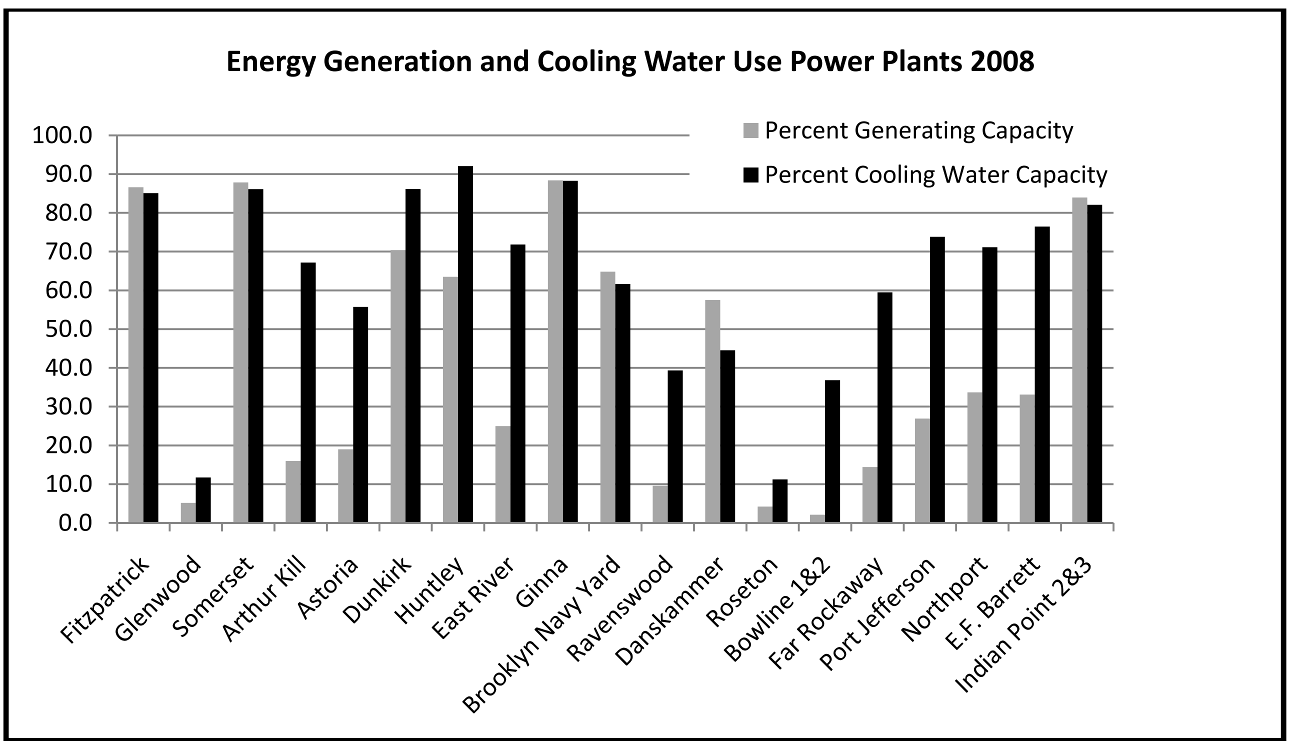

Figure 6: Average electric generating capacity and cooling water capacity utilization at 19 steam electric facilities in New York State during 2008.

As noted previously, the time of year that a facility operates has a tremendous effect on the entrainment impact occurring at the facility (EPRI 2003b). Figure 7 compares the percent capacity utilization of the cooling water system with the resulting percent reduction in entrainment from baseline conditions. At several facilities, the reductions in entrainment are much less than the reductions in water usage. This difference is quite large for peaking facilities such as the Glenwood Generating Station. Again, this is attributable to the fact that these facilities operate at near full-capacity during the late spring and early summer months when ichthyoplankton are most abundant. These facilities also operate their CWIS more often than required to condense steam (*i.e*, the CWIS often operates at design capacity when the facilities are not generating electricity) (Fig. 6). Therefore, simple annualized reductions in electric generating capacity use or cooling water capacity use will not likely result in a significant environmental benefit (*e.g.*, entrainment reduction) being realized. Cooling water use and electric generation reduction must occur when the resource is at risk in order to be an effective management tool in reducing the adverse environmental impact.

The one facility in New York State that has recently reduced entrainment by actively managing cooling water use is the Danskammer facility located on the Hudson River. The DEC has required strict cooling water reductions (*i.e.*, operating variable speed drive pumps and implementing protective outages during biologically active times of the year) which has resulted in a 70 percent reduction in entrainment from baseline conditions (Fig. 7). This demonstrates that cooling water use restrictions can result in reduced aquatic resource impact but these restrictions must be developed based on adequate site specific study.

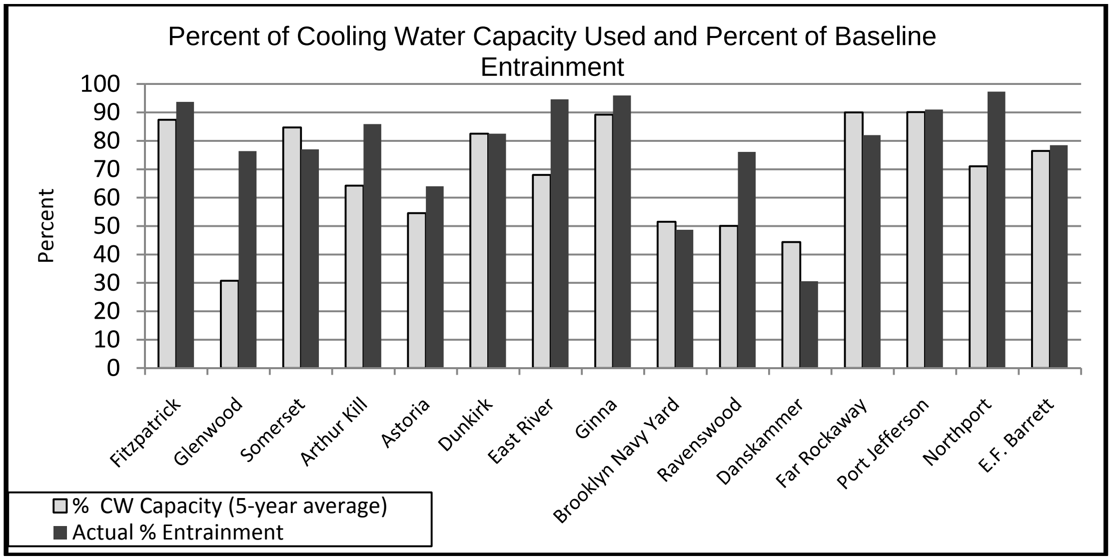

Figure 7: Percent cooling water capacity used and percent of baseline entrainment at 15 steam electric facilities in New York.

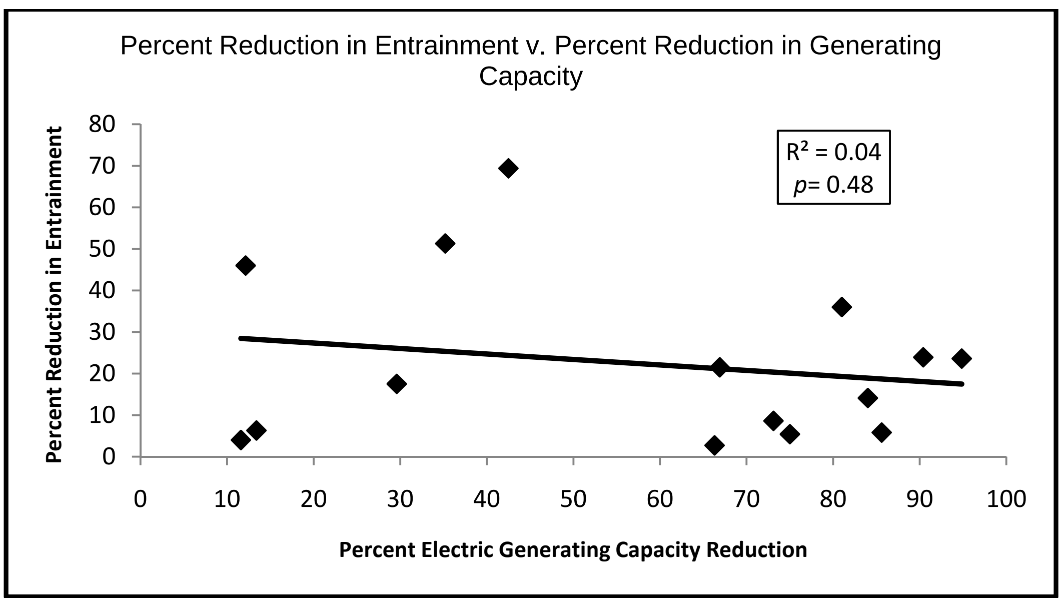

Figure 8: Regression between the percent reduction in entrainment from baseline conditions and the percent reductions in electric generating capacity used. Though not significant, the general relationship indicates that steam electric facilities in New York State utilizing the least amount of electric generating capacity have minimally reduced entrainment from baseline conditions.

Conclusions

Based on the results of this study, non-targeted reductions in cooling water capacity utilization have little effect on reducing the adverse environmental impact caused by the operation of cooling water intake structures in New York State. This finding agrees with conclusions made by EPRI (2003b) that even though there are generally more fish entrained or impinged with increased cooling water use at power plants, volumetric flow rate alone is a poor predictor of this adverse environmental impact. The seasonal dimension of both energy demand and fish reproductive and migratory life history, and cooling water intake system operational practices, are likely the driving factors influencing entrainment and impingement at a facility. Most steam electric facilities in New York operate under peaking and load-following conditions but they still have a disproportionately large adverse impact on the aquatic resource. This finding contradicts assumptions that peaking facilities tend to operate during the times of the year when biological activity would be low and use a proportionately lower amount of cooling water than baseloaded facilities (EPA 2004). Likely explanations for this finding are twofold: (1) these facilities operate during the biologically active times of the year; and (2) the cooling water systems at these facilities operate at much higher levels than is required for energy generation alone. Based on this study, there is not a predictable relationship between the cooling water capacity use, electric generation capacity utilization, and adverse environmental impact at a facility in New York State. Cooling water systems were operated much more often than required to effectively condense steam and remove waste heat at many facilities. Whether for capacity-reliability or financial reasons, the result is that a much larger adverse environmental impact occurs than would be predicted from electric generating capacity utilization alone.

The results of this study also demonstrate that using the full-design capacity of cooling water intake systems in establishing a calculation baseline for entrainment and impingement at an existing industrial facility provides a consistent and stable benchmark across the State for both measuring current and predicting future reductions in adverse impact. The claim that the inclusion of full-design capacity in the baseline calculation exaggerates the level of adverse environmental impact and allows the steam electric industry to continue to cause adverse environmental impact is not supported by these results. Indeed, much of the variability in the reduction in entrainment and impingement observed at steam electric facilities in New York State is a result of factors other than non-targeted reductions in capacity utilization. Since non-targeted reductions in flow account for a minor portion of the overall reductions in the observed impact, use of a calculation baseline that incorporates the full-design capacity of the CWIS provides an accurate way to determine the potential maximum adverse environmental impact at existing steam electric facilities in New York State.

Without proper site-specific evaluations, required or assumed reductions in electric generation capacity utilization may not lead to the minimization in adverse environmental impact required by CWA § 316(b) and 6 NYCRR § 704.5. As demonstrated with power facilities sited in New York State, baseload facilities do use a fairly predictable percent capacity of their CWIS in relation to the amount of electricity being generated and, for the most part, operate the CWIS year round. However, the majority of the steam electric generating facilities in New York generate electricity under peaking or load-following conditions where the reductions in cooling water use and the corresponding adverse environmental impact is far less predictable. The percent capacity of the cooling water intake systems utilized at these facilities varies considerably with some facilities using almost 75 percent of their cooling water capacity while utilizing less than 25 percent of their electric generating capacity. Given that these facilities primarily operate during times of the year when there is a high abundance of many life stages of fish, this disproportional use of cooling water capacity can result in a minimal (ten percent or less) reduction in entrainment from calculation baseline conditions. This finding contradicts previous assumptions that peaking facilities would only have a minimal impact. Therefore, the relationship between electric generating capacity utilization, CWIS capacity utilization, and the resulting impact to aquatic resources through the entrainment and impingement of aquatic organisms needs to be evaluated carefully at a facility before determining if and how any restrictions should be placed on a facility's electric generation or non-contact cooling water use to meet the requirements of CWA § 316(b) and 6 NYCRR § 704.5.

Acknowledgements

All of the biological data (*e.g.*, the facility specific impingement and entrainment estimations) used in the analyses for this report were collected by the electric power generating industry in New York State. The quality of the work undertaken by the environmental consulting firms hired by the power industry provided the level of detail and accuracy required to undertake such an investigation. These biological studies were required through the DEC's State Pollutant Discharge Elimination System (SPDES) permit program and were overseen by New York State DEC biologists. The dedication of the DEC biologists, working closely with consultant biologists resulted in a highly accurate assessment of the impingement and entrainment of aquatic organisms in New York State waters. In addition, several DEC staff provided valuable insight, advice, and review of this technical document including: Michael Calaban, Christina Dowd, Colleen Kimble, and Mark Sanza. Technical staff from the U.S. EPA provided valuable technical review.

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