GOODWIN

Elise N. Zoli
+1 617 570 1612
ezoli@goodwinlaw.com

Goodwin Procter LLP
100 Northern Avenue
Boston, MA 02210

goodwinlaw.com
+1 617 570 1000

October 14, 2016

BY FEDERAL EXPRESS

Kevin T. Folk, Acting Chief
Environmental Review and Project Branch
Division of License Renewal
Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Re: Request to the National Marine Fisheries Service for Section 7 Conference for Indian Point Nuclear Generating Units Nos. 2 and 3 Due to Proposed Rule to List Atlantic Sturgeon Critical Habitat in the Hudson River, dated September 13, 2016

Dear Mr. Folk:

On behalf of Entergy Nuclear Indian Point 2, LLC, Entergy Nuclear Indian Point 3, LLC and Entergy Nuclear Operations, Inc. (collectively, "Entergy"), this correspondence addresses the above-referenced request (the "Request") submitted by the Nuclear Regulatory Commission ("NRC") staff to the National Marine Fisheries Service ("NMFS") for a conference pursuant to Section 7 of the Endangered Species Act. NRC's Request, and its attached technical document titled "Impacts to Proposed Critical Habitat for the Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*), Indian Point Nuclear Generating Units 2 and 3 (collectively, "Indian Point" or "IPEC"), Proposed License Renewal" (the "Evaluation"), address NMFS's pending proposal to designate the Hudson River (among other areas) as critical habitat for the Atlantic sturgeon (the "Proposed Rule").

To facilitate continued informed discussion of the Request, and consistent with 50 C.F.R. § 402.10(c), Entergy respectfully requests the opportunity to participate in that conference process, and hereby submits these comments on the Request to facilitate that discussion.[1] Briefly, Entergy identifies two considerations with respect to the Request:

[1] To that end, this correspondence is also provided to NMFS. Entergy has done so prior to the close of the public comment period on the Proposed Rule (October 14, 2016), so that this correspondence can be treated as supplemental to Entergy's initial September 1, 2016 comments on the Proposed Rule.

- First, as detailed in Entergy's written comments on the Proposed Rule ("Entergy's Comments"), the limited area of the Hudson River within the Indian Point Safety and Security Zone (the "IPEC SSZ") does not contain the necessary characteristics or conditions to support its inclusion in a science-based, critical habitat designation for Atlantic sturgeon. (A copy of Entergy's Comments is attached for your convenience and consideration.) As detailed in Entergy's Comments, extensive, validated Hudson River Biological Monitoring Program ("HRBMP") data and recent New York State Department of Environmental Conservation ("NYSDEC") sturgeon tracking information obtained under applicable freedom of information act law ("FOIL") demonstrate that sturgeon are not present, or likely to be present as a result of unfavorable natural conditions, in the IPEC SSZ. Entergy respectfully submits that the Request should reflect this best available scientific information, which supports exclusion of the IPEC SSZ from the critical habitat designation.

- Second, Mark T. Mattson, Ph.D. of Normandeau Associates, Inc. and John Young, Ph.D. of ASA Analysis & Communication, Inc. reviewed the technical aspects of the Evaluation, and in the process identified certain incorrect statements or assumptions by NMFS regarding various aspects of the Hudson River environment and potential impacts of operations at Indian Point. The following paragraphs provide the mistaken excerpted statement or passage from the Evaluation and our clarification or explanation of the contrary best available scientific information. Entergy further respectfully submits that the Request should reflect this best available scientific information, which supports exclusion of the IPEC SSZ from the critical habitat designation.

Finally, on October 12, 2016, Entergy received an additional response from NYSDEC to its FOIL consisting of more than 500 NYSDEC documents relating to Hudson River sturgeon distribution and habitat. Entergy will be reviewing that information, and expects to provide additional comments to NRC and NMFS on this matter within 30 days. To that end, we respectfully request that the conference or consultation schedule in the NRC Request be lengthened to allow us to do so.

1. The IP2 and IP3 action area could also support larvae in late summer during years where the river's salt wedge is downstream of the IP2 and IP3 intakes (NMFS 2013) (Evaluation at 8).

In fact, the IPEC area does not and could not support larvae in the late summer, even in those increasingly infrequent years when the salt wedge is downstream of IPEC at that time. This is because (1) saline, not freshwater conditions occur in the IPEC region at that time, (2) spawning and nursery habitat are considerably upstream from IPEC with the result that larval distribution is not near IPEC, and (3) late summer post-dates the larval development period in the Hudson River.

First, the salt wedge is typically at or upstream from Indian Point and creates a barrier to Atlantic sturgeon larvae which inhabit freshwater (Geyer and Chant 2006; ASA 2010a (data from 2000-2009); USGS 2001).

Second, Atlantic sturgeon eggs and larvae are both demersal and remain proximate to known spawning grounds located a substantial distance upstream from the IPEC region (ASMFC 2012). Specifically, Entergy had provided NRC with HRBMP data from 1974-2005 at the beginning of the relicensing process in 2007 and 2008. As shown in Table 1, HRBMP data reflects no known Atlantic sturgeon spawning areas, and therefore no likely presence of larvae, in the vicinity of Indian Point. Rather and consistent with the peer-reviewed, published science, Atlantic sturgeon spawn primarily in Hyde Park to Catskill regions (Bain 1997; NMFS 2013 at 42). Indeed, 31 of 45 Atlantic sturgeon larvae (approximately 70%) captured were from these known, discrete spawning areas. Conversely, no Atlantic sturgeon larvae were captured at IPEC in entrainment monitoring from 1980 through 1987, or in that portion of the extensive, river-wide HRBMP surveys conducted within a mile of Indian Point over the last more than four decades. Of the one (1) Atlantic sturgeon and two (2) unidentified sturgeon larvae observed over the forty plus year period of HRBMP monitoring of the seven mile reach of region 4 between Grassy Point and the Bear Mountain Bridge, none was located within the mile occupied by Indian Point (at river mile 42). A single identified Atlantic sturgeon larva was captured at river mile 43. Only four (4) other Atlantic sturgeon larva were even observed downstream of region 7, whose southern boundary is river mile 62, approximately 20 miles north of Indian Point, and these likely arrived there after being transported out of the upstream spawning grounds during a rainfall event.

Third, the temporal distribution of sturgeon larvae (summarized in Table 2) underscores that they could not occupy the IPEC vicinity in late summer. Of the 235 sturgeon larvae collected in HRBMP monitoring from 1974-2005 that continues each year from March through October, only six (6) Atlantic sturgeon -- or less than 3% -- occurred after the end of June (typically week 26), with the latest observation of an Atlantic sturgeon larvae on July 17, 1974 (week 28). Thus, larvae would not be expected to be present in the Hudson in late summer.

For this submission, we have updated the NRC submissions discussed above to reflect HRBMP sampling through 2015. A review of these more recent data underscores that Atlantic sturgeon larvae are present far north of IPEC, and only through the month of June. Specifically, of 14 Atlantic sturgeon larvae collected, all except one (1) were collected in regions 6-11 at least 14 miles north of Indian Point, and all were collected on or before June 11. The only Atlantic sturgeon larva outside these spatial and temporal bounds was a single post-yolk sac larvae ("PYSL") collected at river mile 53, some 11 miles north of Indian Point, on June 13, 2013.

In sum, and consistent with salinity dynamics that continue to exclude sturgeon larvae from the IPEC vicinity, the HRBMP data provided to NRC and updated here demonstrate that over the last four decades Atlantic sturgeon larvae have not occupied, and therefore are not likely to occupy, the Indian Point vicinity, and particularly the IPEC SSZ, in late summer.

Table 1 Spatial distribution of Atlantic and shortnose sturgeon larvae collected in LRS sampling from 1974-2005 from data provided to NRC in 2007 and 2008. Additional unidentified sturgeon larvae not previously provided to NRC.

Region	River miles	Atlantic Sturgeon	Shortnose Sturgeon	Unidentified Sturgeon	Total
12 –Albany	125-152	6	42	37	85
11-Catskill	107-124	16	3	7	26
10-Saugerties	94-106	0	1	2	3
9-Kingston	86-93	1	2	6	9
8-Hyde Park	77-85	14	17	15	46
7-Poughkeepsie	62-76	3	0	46	49
6-Cornwall	56-61	0	0	6	6
5-West Point	47-55	4	0	4	8
4-Indian Point	39-46	1	0	2	3
Total		45	65	125	235

Table 2 Temporal distribution of Atlantic and shortnose sturgeon larvae collected in LRS sampling from 1974-2005 from data provided to NRC in 2007 and 2008. Additional unidentified sturgeon larvae not previously provided to NRC.

Week	Atlantic Sturgeon	Shortnose Sturgeon	Unidentified Sturgeon	Total
17	0	0	1	1
18	0	0	0	0
19	0	27	24	51
20	6	8	17	31
21	1	5	12	18
22	10	7	32	49
23	24	17	12	53
24	1	1	8	10
25	2	0	12	14
26	0	0	2	2
27	0	0	2	2
28	1	0	3	4
Total	45	65	125	235

2. Impingement and entrainment can affect critical habitat by removing prey from the habitat. Atlantic sturgeon adults and migrant subadults prey on mollusks, gastropods, amphipods, annelids, decapods, isopods, and fish such as sand lance (Family Ammodytidae) (NMFS 2013). Although specific impingement and entrainment information is not available for Atlantic sturgeon prey, the NRC (2015) assessed impingement and entrainment on representative important species in its draft second supplement to the IP2 and IP3 FSEIS and concluded that impingement and entrainment effects would vary from small to large depending on the specific species. The NMFS (2013) addressed effects specifically to Atlantic sturgeon prey species from the continued operation of IP2 and IP3 in its biological opinion and concluded that effects would be insignificant and discountable. Therefore, the NRC concludes that impingement and entrainment would not affect Atlantic sturgeon prey species to a degree that would inhibit the growth, development, recruitment, or survival or juveniles, subadults, or adult Atlantic sturgeon or otherwise appreciably diminish the value of the proposed critical habitat for the New York Bight DPS of Atlantic sturgeon (Evaluation at 9).

The focus on potential prey impacts of impingement and entrainment reflects a series of mistaken assumptions that warrant correction.

There is no credible scientific evidence that Atlantic sturgeon will not consume prey that is impinged or entrained and returned to the ecosystem, even if damaged by that process, which is unlikely for the organisms that constitute the majority of the Hudson River Atlantic sturgeon's diet. Assuming that NMFS' seven (7) prey categories, replicated in Table 3, are correct, six (6) of these prey categories are either epibenthic or infaunal, and as such are too small to be impinged, not entrained in substantial numbers and known to experience entrainment survival. Specifically, by way of example, Haley (1999) reported the food items of juvenile Atlantic (n=24) sturgeon collected in the Hudson River in 1995-1996. She found that the diet of these juvenile Atlantic sturgeon was dominated by Crustacea (49%), which survive entrainment well, and Polychaeta (46%), a group that lives in the bottom sediment and is not susceptible to entrainment.

Table 3 Sturgeon prey groups, as listed by NMFS (2013), their primary habitats, and susceptibility to entrainment, impingement, and thermal plume effects due to IPEC operation.

Prey Group	Habitat	Entrainment	Impingement	Thermal Plume
Mollusks	Early larval stages pelagic, benthic once settled	Only prior to settlement, if in vicinity of intake	Not subject to	Plume not in contact with bottom
Gastropods	Benthic	Not present in water column.	Not present in water column. Too small to be impinged.	Plume not in contact with bottom
Amphipods	Most epibenthic and burrowing	Some entrainment when move into	Too small to be impinged.	Plume temperatures

		water column at night. Have been demonstrated to survive entrainment at IPEC.		not high enough to cause mortality.
Annelids	Benthic infauna.	Not present in water column.	Not present in water column. Too small to be impinged.	Plume not in contact with bottom
Decapods	Larval stages pelagic, then epibenthic. Common species at IPEC (blue crab) capable swimmer.	Pelagic stages typically not in IPEC vicinity.	Juveniles and adults only. Blue crabs common at times. High survival rate.	Plume not in contact with bottom
Isopods	Epibenthic and burrowing	Some entrainment when move into water column.	Too small to be impinged.	Plume not in contact with bottom
Fish	Benthic forms only	Could be entrained.	Could be impinged.	Plume not in contact with bottom

Table 4 Diet of juvenile Atlantic and shortnose sturgeon in the Hudson River. Data from Haley (1999).

Taxon	NMFS Prey Group	Atlantic sturgeon		Shortnose sturgeon	
		N	% Composition	N	% Composition
Nematoda	Not included	2	1%	0	0%
Nemertea	Not included	4	2%	119	3%
Gastropoda	Gastropod	0	0%	164	4%
Bivalvia	Mollusc	1	1%	162	4%
Polychaeta	Annelid	92	46%	3	0%
Oligochaeta	Annelid	0	0%	349	9%
Crustacea	Includes Amphipods	98	49%	2857	77%
Gammeridae	Amphipods	25	13%	2717	73%
Mysidae	Not included	1	1%	0	0%
Chelicerata	Not included	0	0%	2	0%
Insecta	Not included	1	1%	65	2%
Total		198	100%	3721	100%

Another source cited by NMFS (2013), Guilbard et al. (2007), showed results similar to Haley (1999), with Oligochaetes and Gammerids as key portions of the diet. Even if certain of these were subject to entrainment mortality, which is unlikely, there is no scientific support for the proposition that Atlantic sturgeon do not consume morbid or dead epibenthic or infaunal organisms. Thus, and because Indian Point returns its intake water to the Hudson, with the result that there is no net loss of biomass from the use of its circulating water, there is no demonstrated scientific basis for concern regarding a loss of prey.

Even assuming amphipods and blue crab were required to be live, which has not been shown as a scientific matter, there is no reasonable concern about IPEC impingement or entrainment of amphipods and blue crab. To the contrary, amphipod entrainment and blue crab impingement have both been examined at IPEC, and these groups have been shown to have excellent survival following encounters with Indian Point's intake structure and system. Specifically, Ginn (1977) found no significant difference in survival of entrained *Gammarus*, in comparison to unentrained control organisms, during two years of studies at IPEC Unit 2. Prior to the installation of the current intake technology (continuously rotated Ristroph-type traveling screens), studies of survival of impinged blue crab resulted in an average survival rate between 1983 and 1990 of 83% (EA 1991). With the current technology, survival would be expected to be even higher.

Of the seven (7) prey categories identified as relevant by NMFS, only one (1) category, fish, would be potentially susceptible to entrainment effects (Table 3). Specifically, Atlantic sturgeon are known to consume sand lance (Bigelow and Schroeder 1953) and Atlantic tomcod (Guilbard et al. 2007). Sand lance was not present in any entrainment sampling conducted from 1983-1987 at Indian Point, and Atlantic tomcod have high rates of entrainment and impingement survival (EA 1981, Fletcher 1990).

In sum, there is no credible evidence that operation of IPEC's CWIS would have any, let alone deleterious effects, on the vast majority of Atlantic sturgeon prey or that any such effects would impair their value as prey.

3. *Regarding water use, IP2 and IP3 could physically remove roughly 16 to 27 percent of the habitat from the Hudson River aquatic environment based on average annual river flow data from the past five water years and assuming operation at 100 percent of the licensed thermal power level (Evaluation at 10).*

This statement misunderstands the nature of IPEC's intake and discharge, which are effectively simultaneous, and therefore involves no loss of Hudson River water and, therefore, habitat.

Even if NRC were to insist on assuming that circulating water that is actually returned to the Hudson can be treated as removed from the habitat, NRC greatly overstates the actual proportion of that water that IPEC withdraws, and therefore returns, to the Hudson River.

Specifically, as stated by NRC for this calculation, the water (which in turn equated to "habitat") is considered to be the freshwater input to the estuary that is measured solely as water flowing over the Federal Dam at Green Island, approximately 110 miles upstream from IPEC. This calculation ignores two major important categories of inputs to actual Hudson River flow necessary to an accurate statement of the physical habitat:

First, there are many other sources of freshwater input to the estuary in addition to the Federal Dam at Green Island, which accounts for only approximately 2/3 of the total freshwater input (Darmer 1987). Thus, based on this consideration alone, NRC's estimate of freshwater flow is substantially understated.

Second, and even more importantly, as clearly spelled out in NMFS' description of Critical Habitat, the entire estuary represents a "salinity gradient," which means that the water or flow passing Indian Point (which NRC equates conceptually to "habitat") actually consists of fresh water mixed with saline water.

Therefore, for the calculation of IPEC's fraction of theoretically removed water to have a credible empirical basis, the denominator of the calculation needs to be the entire volume of water flowing through the action area – that is, not only by the correct (more complete) net downstream flow, but also the tidal movement of water upstream and then downstream.

Applying this conceptual framework, Entergy offers the following suggested clarification to the Request. Darmer (1987), citing Stedfast (1982), indicates that tidal flow below Poughkeepsie is usually more than 200,000 cubic feet per second ("cfs"). More recent information from the United States Geological Survey ("USGS"), available at http://waterdata.usgs.gov/usa/nwis/uv?site_no=01372058, indicates a peak tidal flow for this region of 240,000 cfs. Conservatively using the 200,000 cfs figure for a peak tidal flow near Indian Point, the maximum design flow for IPEC's circulating water system, all of which is discharged back to the Hudson (measured as 1,680,000 gallons per minute, which equals 3,744 cfs) represents no more than 1.9% of the maximum peak tidal flow past the Stations. Enercon (2010) provides a similar value of 1.7% based upon the average tidal flow near Indian Point and historic actual intake flows at IPEC from 2001-2008 (note that Enercon's average tidal flow value of 80,000,000 gallons per minute equates to 178,240 cfs).

Finally, equating incremental percentages of flows of complex tidal systems with diverse populations that simply do not use the entire water column or depend on an incremental portion of it is a questionable approach to measuring "habitat."

4. *Thermal impacts on sturgeon can include heat shock, which can result in direct mortality; sublethal effects, such as stunning or disorientation, which can alter predator-prey interactions by increasing susceptibility of affected individuals to predation; and an increase in susceptibility to disease or parasitism (NRC 2013). Additionally, discharge of heated water has*

the potential to create barriers that prevent or delay access to other areas within the river (NMFS 2013) (Evaluation at 10).

The Evaluation recites potential effects of a thermal discharge on Atlantic sturgeon as characterized by NMFS. However, although Indian Point has operated for more than 40 years, none of these potential effects has been observed, and based on state of the art, NYSDEC-validated thermal assessments, none would be expected to occur. Indeed, IPEC's thermal discharge, which complies with New York State water quality standards (ASA 2011), occurs primarily in the upper portion of the water column (ASA 2010) and therefore is highly unlikely to have an adverse effect on benthic species, such as Atlantic sturgeon. Indeed, NRC (2013) and NMFS (2013) have correctly reached the conclusion that IPEC's thermal discharge will not threaten either sturgeon species.

Moreover, from May through July of 1982 through 2015, a standardized HRBMP data set comprising 17,990 measurements of temperature, dissolved oxygen concentrations, and salinity have been taken from within 0.5 m of the bottom substrate of the Hudson River estuary from Yonkers to Albany (River Miles 12-152), with 1,836 measurements in the seven-mile reach of region 4 (where Indian Point is located). These data demonstrate that water temperatures measured in the near bottom habitat occupied by Atlantic sturgeon have consistently been less than 30°C, except in the Yonkers region just upstream from New York City. In the Indian Point region, 95% of the bottom water temperatures were less than 25.4°C during this period, with a single maximum water temperature over that more than 30-year period of 28.1°C.

****

Thank you for your consideration of this submission. We look forward to discussing our perspectives on the Request and to participating in any conference process that arises from your Request. In the interim, if you have any questions regarding Entergy's Comments on the Proposed Rule or this correspondence, please do not hesitate to contact Dara Gray at Indian Point (914.254.8414 or DGray@entergy.com) or me.

Sincerely,

Elise N. Zoli

ENZ
Enclosures

cc: Ms. Kimberly Damon-Randall, National Marine Fisheries Service
Mr. Fred Dacimo
Mr. Robert Walpole
Ms. Bill Glew, Esq.
Ms. Kelli M. Dowell, Esq.
Ms. Dara Gray

References

Applied Science Associates, Inc. (ASA). 2010. Hydrothermal modeling of the cooling water discharge from the Indian Point Energy Center to the Hudson River. ASA Project 09-167. 22 March 2010. Prepared for Indian Point Energy Center, Buchanan, NY.

Applied Science Associates, Inc. (ASA). 2010a. Estimate of Salinity in the Hudson River at Indian Point Energy Center.

Applied Science Associates, Inc. (ASA). 2011. Final Report. 2010 field program and modeling analysis of the cooling water discharge from the Indian Point Energy Center. ASA Project 2009-167. 31 January 2011. Prepared for Indian Point Energy Center, Buchanan, NY.

Atlantic States Marine Fisheries Commission. 2012. Habitat Addendum IV to Amendment 1 to the Interstate Fishery Management Plan for Atlantic Sturgeon.

Bain, M.B. 1997. Atlantic and shortnose sturgeons of the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48:347-358.

EA (Ecological Analysts). 1981. Indian Point Generating Station Entrainment Survival and Related Studies 1979 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority.

EA Engineering, Science, and Technology. 1991. Hudson River Ecological Study in the Area of Indian Point 1990 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority.

Enercon Services, Inc. (Enercon). 2010. Evaluation of alternative intake technologies at Indian Point Units 2 &3. Prepared for Entergy Nuclear Indian Point 2, LLC and Entergy Nuclear Indian Point 3, LLC. February 12, 2010.

Fletcher, R.I. 1990. Flow dynamics and fish recovery experiments: water intake systems. Trans. Am. Fish Soc. 119(3): 393-415.

Geyer, W.R. and R. Chant. 2006. The physical oceanographic processes in the Hudson River Estuary. Pages 24-38 in: Levinton, J. S. and J.R. Waldman. 2006. The Hudson River Estuary. Cambridge University Press. New York. 471 p.

Ginn, T. C. 1977. An Ecological Investigation of Hudson River Macrozooplankton in the Vicinity of a Nuclear Power Plant. Ph.D. Dissertation. New York University.

Guilbard, F. J. Munro, P. Dumont, D. Hatin, and R. Fortin. 2007. Feeding ecology of Atlantic sturgeon and lake sturgeon co-occurring in the St. Lawrence Estuarine transition zone. American Fisheries Society Symposium 56:85-104.

Haley, N. J. 1999. Habitat Characteristics and Resource Use Patterns of Sympatric Sturgeons in the Hudson River Estuary. Master of Science Thesis. University of Massachusetts Amherst.

National Marine Fisheries Service. 2013. Biological Opinion/Incidental Take Statement, Indian Point.

Nuclear Regulatory Commission. 2013. Generic Environmental Impact Statement for License Renewal of Nuclear Plants: Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 – Final Report Supplemental Report and Comment Responses (NUREG-1437, Supplement 38, Volume 4).

United States Geological Survey. 2001. Salt-front Movement in the Hudson River Estuary, New York – Simulations by One-Dimensional Flow and Solute-Transport Models.

GOODWIN

Goodwin Procter LLP
100 Northern Avenue
Boston, MA 02210

goodwinlaw.com
+1 617 570 1000

September 1, 2016

Kimberly B. Damon-Randall
Assistant Regional Administrator
Protected Resources Division
National Marine Fisheries Service
Greater Atlantic Regional Office
55 Great Republic Drive
Gloucester, MA 01930

Re: **Endangered and Threatened Species; Designation of Critical Habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay Distinct Population Segments of Atlantic Sturgeon – Proposed Rule; NOAA-NMFS-2015-0107**

Dear Ms. Damon-Randall:

On behalf of Entergy Nuclear Indian Point 2, LLC, Entergy Nuclear Indian Point 3, LLC and Entergy Nuclear Operations, Inc. (collectively, "Entergy"), we respectfully submit these comments ("Comments") on the above-referenced proposed rule designating critical habitat for the Gulf of Maine, New York Bight and Chesapeake Bay Distinct Population Segments of Atlantic Sturgeon (the "Proposed Rule").[1]

Our focus is on a specific area of the Hudson River in the immediate vicinity of Entergy's Indian Point Energy Center ("Indian Point"). Sections A through C below provide important background information. Section A provides information on Entergy and Indian Point, including Entergy's longstanding commitment to environmental stewardship. Section B describes Entergy's history of consultation with the National Marine Fisheries Services ("NMFS"), at the conclusion of which NMFS determined that Indian Point's continued operations over the next two decades will not jeopardize the continued existence of the New York Bight Distinct Population Segment ("NYB DPS") of Atlantic sturgeon (or shortnose sturgeon not subject to the Proposed Rule). Section C describes the world-class, long-term biological monitoring program in the Hudson River known as the Hudson River Biological Monitoring Program ("HRBMP"), which has provided important data on a wide variety of aquatic species, including Atlantic sturgeon.

Our specific comments on the Proposed Rule are addressed in Sections I through III below. Section I focuses on the breadth of the critical habitat designation and demonstrates that the area of the Hudson River within 1000 feet (300 meters) of Indian Point ("Indian Point Vicinity") should be excluded from the critical habitat designation due to (a) the absence in the Indian Point Vicinity of those physical and biological features indicative of critical habitat during any relevant Atlantic sturgeon life stage; (b) the presence of the United States Coast Guard ("USCG") created safety and security zone designed to protect against terrorist or other activities, which could be adversely impacted by the critical habitat designation, and (c) the fact that the benefits of excluding the Indian Point Vicinity and safety and security zone far outweigh any benefits of including it in the critical habitat designation. Section II addresses NMFS' failure to review and rely upon the best scientific data available for the NYB DPS, including based upon

[1] 81 Fed. Reg. 35701.

extensive scientific studies of Atlantic sturgeon in the Hudson River that NMFS itself has authorized, but the results of which NMFS has not accounted for in the Proposed Rule. Section III supports NMFS' conclusions that the designation of critical habitat should have no effect on facilities, such as Indian Point, that have already completed consultation with NMFS as a consequence of the listing of Atlantic sturgeon as an endangered species in 2012.

A. Background on Entergy.

Entergy is the owner and operator of Indian Point, located in the Village of Buchanan, New York, along the eastern shore of the Hudson River. Indian Point consists of one retired (Unit 1) and two actively operating nuclear generating stations (Units 2 and 3). Indian Point has a maximum dependable electric generating capacity of approximately 2,069 megawatts ("MW") or more than 2 Gigawatts ("GW," representing one billion watts).[2] Indian Point provides a substantial percentage of metropolitan New York's electricity, and therefore anchors the baseload supply that advances electric-system reliability and affordability goals that underpin the New York economy. Indian Point's operations further federal and state goals of reducing emissions of pollutants in New York State[3], especially in the non-attainment area of downstate New York, as well as contributing toward the achievement of federal and New York Climate Change mitigation goals. Indian Point is an important economic engine to the regional economy, employing approximately 1,050 persons on a full-time basis with highly favorable compensation and benefits – an average of over 500 persons at each operating Unit to manage the facilities in a safe, secure and vital manner.[4]

Mirroring Entergy's commitment to the New York electric system is Entergy's (and its parent corporation, Entergy Corporation's) commitment to environmental stewardship. This commitment is underscored by Entergy Corporation's outstanding record of environmental performance and recognized work to promote sustainability. Indeed, on the strength of its industry-leading environmental performance, Entergy Corporation consistently has been listed on the Dow Jones Sustainability North America Index, the Dow Jones Sustainability World Index, the S&P 500 Climate "A" List and the Carbon Disclosure Leadership Index. Entergy Corporation also has been a leader in supporting energy efficiency efforts, recycling and waste reduction, and wetlands restoration, including through its major contributions to the work of the America's WETLAND Foundation. These and Entergy Corporation's other sustainability and environmental stewardship efforts are detailed in its annual report.[5]

B. Background on Entergy's current BiOP/ITS for Atlantic and shortnose sturgeon.

Indian Point operates subject to and with the benefit of operating licenses (one for Unit 2 and one for Unit 3) issued by the Nuclear Regulatory Commission ("NRC"). In 2007, Entergy submitted an application to the NRC to renew those operating licenses for an additional twenty-year period.

---

[2] *See* Entergy, Indian Point Energy Center, http://www.entergy-nuclear.com/plant_information/indian _point.aspx (last visited August 23, 2016).

[3] S*ee, e.g.*, NYSDEC, State Implementation Plans and State Plans http://www.dec.ny.gov/chemical/8403.html (last visited August 23, 2016.

[4] *See, e.g.*, http://www.entergy-nuclear.com/plant_information/indian _point.aspx (last visited August 23, 2016).

[5] *See, e.g.*, Entergy Corporation, Integrated Report (2015), available at http://www.integratedreport.entergy.com

As a result of that application, the NRC commenced consultation with NMFS under Section 7 of the Endangered Species Act ("ESA"). That consultation led initially to a Biological Opinion/Incidental Take Statement in October 2011, which concluded that the continued operation of Indian Point Units 2 and 3 through 2033 and 2035, respectively, was not likely to jeopardize the continued existence of shortnose sturgeon. Following the listing of the Atlantic sturgeon as an endangered species in February 2012, NRC re-initiated consultation with NMFS to address that species. On January 30, 2013, NMFS issued Entergy's current Biological Opinion/Incidental Take Statement (the "Indian Point BiOp/ITS").

The Indian Point BiOp/ITS concluded that continued operations at Indian Point through 2033 and 2035 (for Units 2 and 3, respectively) are unlikely to jeopardize the continued existence of both shortnose and Atlantic sturgeon, establishing incidental take limits for both species. That operative decision includes numerous technical statements by NMFS about the unsuitability of the Indian Point Vicinity as critical habitat for Atlantic sturgeon, including the well-documented absence of any nursery, resident juvenile or resident adult habitat in that Vicinity. *See* Indian Point BiOp/ITS, *passim.* These statements are discussed in detail in the Comments below.

C. **Background on the longstanding, world class Hudson River Biological Monitoring Program.**

The HRBMP is a continuing and extensive annual biological monitoring program that, from 1966 to the present, has been conducted on behalf of Entergy (and its predecessors and other Hudson River electric generating facilities) under the direction and oversight of NYSDEC, with the purposes of understanding the relative spatial and temporal distribution, health and trends of Hudson River aquatic species, as well as of assessing potential impacts on those species of several electric power generating stations (including Indian Point). The HRBMP consists of a multitude of individual sampling surveys, typically performed throughout the tidal Hudson River for a substantial portion of each year, each of which targets different life stages of fish in their habitat through the use of appropriate sampling gear and procedures.

Normandeau Associates, Inc. ("Normandeau"), a nationally recognized environmental consulting firm, is responsible for the HRBMP field efforts and has been for decades. It develops protocols for the program on a yearly basis which are circulated to NYSDEC for review and approval prior to the onset of sampling. After collecting data from the River, Normandeau fisheries scientists process relevant data from those samples, which number hundreds of thousands of organisms, chiefly fish species, each year. The Normandeau process includes identifying the species and life stage of each organism, as well as enumerating the number of each species, their sizes, when and where they were found, and various environmental conditions at the time of collection. All of these data are entered into a standardized database as data files and subjected to a rigorous quality assessment/quality control ("QA/QC") protocol that has become the industry standard. The QA/QC process includes both reprocessing of randomly selected samples and logical checks to ensure data transcription accuracy and the validity of the recorded values. The process also includes the preparation of weekly reports that Normandeau sends to NYSDEC which include weekly and cumulative tables of the program's efforts and results.

Once Normandeau has quantified the relevant contents of these samples, performed the QA/QC re-inspection, and prepared the quality-checked data files, these files are forwarded to another nationally-recognized environmental consulting firm, ASA Analysis & Communications, Inc. ("ASA"). ASA specializes in analyzing such data, including relative abundance and the potential impacts from the Hudson River power plants. ASA performs an additional level of validation on the data and then uses it to prepare annual reports summarizing that year's survey results, which are submitted to NYSDEC for its review and approval.

The HRBMP's 50-year dataset is widely regarded as the most extensive and continuous fisheries monitoring program of its type performed in the United States, which has generated the most robust set of data on potential impacts of power plants in the world. Indeed, Dr. John Waldman (formerly with the Hudson River Foundation for Science and Environmental Research, Inc., an independent foundation dedicated to research on the Hudson River ecosystem, and now on the faculty of Queens College) has stated in a peer-reviewed publication that "the Hudson is one of the most scientifically studied rivers in the world," with the period since 1981 that has been a focus of the HRBMP representing a "golden age of Hudson River research, much of it centered around fishes," and reflecting "a detailed, long-term understanding of fish populations in the Hudson."[6] Likewise, the HRBMP dataset has been characterized by NYSDEC staff (in comments to the United States Environmental Protection Agency ("EPA")) as "probably, the best dataset on the planet,"[7] and its value has only grown more robust since that NYSDEC submission was made.

COMMENTS ON THE RULE

I. Based on the Best Scientific Data Available, The Area Designated as Critical Habitat in the Hudson River Is Overbroad with Regard to the Indian Point Vicinity.

The Proposed Rule designates the entire length, breadth and depth of the Hudson River from Battery Park to the Federal Dam at Troy – more than 154 river miles, which has a span as wide as 3.5 miles from bank to bank in certain locations – as critical habitat for the Atlantic sturgeon.[8]

As detailed below, NMFS appears to have done so without specific examination of the geographic areas within the River that meet the definition of critical habitat, *i.e.*, that possess those physical or biological features essential to the conservation of the species, based on the best scientific data available. Had NMFS done so with respect to the Indian Point Vicinity, it would have concluded that the area should be excluded on biological and ecological grounds.

Specifically and consistent with the Comments below, Entergy respectfully submits that this designation is overbroad with respect to the Indian Point Vicinity and, therefore, is inconsistent with NMFS' ESA obligation to designate specific areas as critical to species conservation, where practicable.

A. The Indian Point Vicinity Is Not Biologically Supported As Critical Habitat.

According to 16 U.S.C. § 1532(5)(A)(i), the term "critical habitat" is defined as:

> (i) The *specific areas* within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 1533 of this title, on which are

[6] Waldman, J. R., K. E. Limburg, and D. L. Strayer. 2006. The Hudson River environment and its dynamic fish community. Pages 1–7 in J. R. Waldman, K. E. Limburg, and D. L. Strayer, editors. Hudson River fishes and their environment. American Fisheries Society, Symposium 51, Bethesda, Maryland ("Waldman, et al. 2006").

[7] See Letter from William Sarbello (then-a NYSDEC staff person) to Proposed §316(b) Rule Comment Clerk, EPA (November 9, 2000).

[8] *See, e.g.,* 81 Fed. Reg. 35717 (designating as critical habitat "Hudson River from the Troy Lock and Dam ... downstream to where the main stem river discharges at its mouth into New York City Harbor"); United States Geological Survey's National Water Quality Assessment Program – The Hudson River Basin. (http://ny.water.usgs.gov/projects/hdsn/fctsht/su.html) (last visited August 30, 2016).

> found those physical or biological features *(I) essential to the conservation of the species and (II) which may require special management considerations or protection …*
>
> (ii) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 1533 of this title, upon a determination by the Secretary that such areas are *essential for the conservation of the species.* [9]

Importantly, except in specific circumstances determined by NMFS, critical habitat "shall *not* include the entire geographical area which *can be occupied* by the threatened or endangered species."[10] Thus, simply because an area can be occupied by an Atlantic sturgeon is not, without more, a basis to designate an area as critical habitat. Rather, the analysis must be far more searching, for to be a critical habitat, the area in question must be "essential to the conservation of the species …"

Habitat "essential to the conservation of the species" could be "essential" in several ways pertinent to the Atlantic sturgeon. It could be essential for successful continued "reproduction and recruitment" of Atlantic sturgeon (critical to spawning success), because, *e.g.*, it provides suitable spawning habitat. It could be critical to juvenile growth, development and migration because, *e.g.*, it enables functional foraging. Or it could be critical to adult maintenance and migration because, *e.g.*, it offers unimpeded movement between the Atlantic Ocean and spawning grounds.

In the Proposed Rule, NMFS did identify certain physical features essential for "reproduction and recruitment" of Atlantic sturgeon – and therefore the critical habitat designation:

- Hard bottom substrate (*e.g.*, rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (*i.e.*, 0.0 to 0.5 parts per thousand range) for settlement of fertilized eggs, refuge, growth, and development of early life stages;

- Aquatic habitat with a gradual downstream salinity gradient of 0.5 to 30 parts per thousand and soft substrate (*e.g.*, sand and mud) downstream of spawning sites for juvenile foraging and physiological development;

- Water of appropriate depth and absent physical barriers to passage (*e.g.*, locks, dams, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: (1) unimpeded movement of adults to and from spawning sites; (2) seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary; and (3) staging, resting, or holding of subadults or spawning conditions adults. Water depths in main river channels must also be deep enough (*e.g.*, $\geq$1.2 m) to ensure continuous flow in the main channel at all times when any sturgeon life state would be in the river; and

- Water, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: (1) spawning; (2) annual and interannual adult, subadult, larval, and juvenile survival; and (3) larval, juvenile, and subadult growth, development and

---

[9] 16 U.S.C. § 1532(5)(A) (emphases supplied).

[10] 16 U.S.C. § 1532(5)(C) (emphasis supplied); 81 Fed. Reg. 35702 (same).

> recruitment (*e.g.*, 13°C to 26°C for spawning habitat and no more than 30°C for juvenile rearing habitat, and 6 mg/L dissolved oxygen for juvenile rearing habitat).[11]

As detailed below in Section II, Entergy does not fully agree with that listing of essential habitat features. For present purposes, however, what is important is that NMFS did not designate with appropriate detail, based on the "best scientific data" available,[12] the "specific areas" of the Hudson River that *actually contain, or would upon restoration contain*, the physical features that are "essential" to the Atlantic sturgeon and therefore reasonably could be considered critical habitat. *See* Draft Biological Information and ESA Section 4(b)(2) Source Document with Draft Economic Analysis and Initial Regulatory Flexibility Analysis ("Biological Information Document") at 2 ("We [i.e., NMFS] were responsible for: ... Identifying specific areas that contain these features and delineating the area(s) by specific limits using landmarks, reference points or lines.").[13] NMFS instead designated the entire Hudson River below the Troy Dam. While that broad level of detail might be appropriate if the evidence were that Atlantic sturgeon use that entire, 154-mile stretch of river on an undifferentiated basis, or that all parts of that stretch of the river are in fact "critical" to the Atlantic sturgeon, that is not the case. As explained herein and demonstrated in the Attachments to these Comments, the best scientific data available is that only well-known stretches of the Hudson River below the Troy Dam are reasonably considered critical habitat to the Atlantic sturgeon, and the critical habitat designation readily could be tailored to exclude those areas where Atlantic Sturgeon either are not present or are highly unlikely, for biological or physiological reasons, to be present . Nor do Atlantic sturgeon use the entire breadth of the Hudson equally; rather, as also explained herein and is shown in the Attachments, in some stretches of the Hudson River, Atlantic sturgeon use only the "deep channel" of relatively narrow breadth, avoiding shoreline areas. In such a situation, a more refined approach to characterizing the critical habitat is appropriate.[14]

The "best scientific data" in this regard is readily accessible. Attachment A to these Comments is a series of images prepared by ASA identifying all of the locations within the Hudson River where relevant HRBMP sampling events, each of which can contain multiple to hundreds of various life stages of fish, have occurred during the period 2000-2014 (when GPS coordinates were available). (The shoal-oriented Beach Seine Survey ("BSS") was not included.) These images reflect in excess of 85,000 sampling events ("all gear" again except BSS), randomly selected and sampled during each survey according to a stratified random sampling plan, with specific samples marked in red at locations where an Atlantic sturgeon was captured. These images show that the vast majority of Atlantic sturgeon are located in the deep channel, proximate to the Hudson's west bank and opposite Indian Point (located on the east bank), and are overwhelmingly captured on the bottom (comparing "all gear" and "bottom gear"). These images also show that the HRBMP sampling design strategy effectively covers the Hudson River habitat, leaving no relevant area unevaluated, with the trivial exceptions of the locations where bottom trawling cannot occur safely due to obstructions, *e.g.*, under the Bear Mountain Bridge (at reference point 44) and the

[11] 81 Fed. Reg. at 35708-09.

[12] 16 U.S.C. § 1533(b)(2).

[13] Indeed, NMFS concluded that it did not have sufficient data to identify physical or biological features of estuaries for foraging and growth that are essential to the conservation of the NYB DPS, nor could it identify such features in the marine environment essential to conservation of the NYB DPS. *See* 81 Fed. Reg. 35709.

[14] *See, e.g.*, Revisions to the Regulations for Impact Analyses of Critical Habitat, 77 Fed. Reg. 51503, 51506 (Aug. 24, 2012) (explaining that "a relatively fine-scale analysis" is more appropriate for "a narrow endemic species," as the Atlantic sturgeon is within the Hudson); Revisions to the Regulations for Impact Analyses of Critical Habitat, 78 Fed. Reg. 53058, 53070 (Aug. 28, 2013) (explaining that a "very fine scale" designation may be employed with respect to such species).

immediate vicinity of Indian Point (reference point 40), as a function of the pipeline crossing and the Indian Point safety and security zone, established in 2001. The similarities between Attachments A and B, described below, underscore the fact that Atlantic sturgeon occupy known, well-defined or delineated areas, none of which are within the Indian Point Vicinity.

Attachment B to these Comments is two figures prepared by Normandeau identifying the locations of Atlantic sturgeon from data collected during NYSDEC's sturgeon tracking program in 2012 and 2013.[15] These 15 tagged juvenile (>300 mm total length) Atlantic sturgeon were rarely found near Indian Point, which is unsurprising because the Indian Point Vicinity generally lacks the characteristics NMFS identified as critical for the sturgeon. Instead, the tagged juvenile Atlantic sturgeon demonstrated a clear preference for the deep middle channel and the west bank of the Hudson. Because the tagging effort was intended to assess Hudson River Atlantic sturgeon movement in the Hudson River, it illustrates that habitat use of the nearshore Indian Point Vicinity is virtually nonexistent.

The reason why Atlantic sturgeon are so rarely found near Indian Point, as Attachments A and B demonstrate, is clear: As discussed on the following pages, the best scientific data available demonstrates that the Indian Point Vicinity does not possess characteristics of value to Atlantic sturgeon at any life stage.

Spawning, Eggs and Larval Sturgeon

It is well understood that Atlantic sturgeon spawn in freshwater that features hard bottom substrate such as cobble, coarse sand, hard clay and bedrock.[16]

Spawning sites within the Hudson River that feature these very attributes have been well documented in various peer-reviewed, scientific publications, as reflected in the Indian Point BiOp/ITS:

> The area around Hyde Park (approximately rkm134) has consistently been identified as a spawning area through scientific studies and historical records of the Hudson River fishery (Dovel and Berggen, 1983; Van Eenennaam *et al.*, 1996; Kahnle *et al.*, 1998; Bain *et al.*, 2000). Habitat conditions at the Hyde Park site are described as freshwater year round with bedrock, silt and clay substrates and water depths of 12-24 m (Bain *et al.*, 2000). Bain *et al.* (2000) also identified a spawning site at rkm 112 based on tracking data. The rkm 112 site, located to one side of the river, has clay, silt and sand substrates, and is approximately 21-27 m deep (Bain et al., 2000).[17]

---

[15] Entergy received a partial response to its New York Freedom of Information Law ("FOIL") request for tracking data for Atlantic sturgeon compiled by NYSDEC, which allowed Normandeau to plot the data from 2012-2103. Entergy has filed a deficiency notice to that partial response and will file a timely challenge, if required, in order to obtain the balance of the tracking information from NYSDEC. Entergy therefore expects to file supplemental comments on the Proposed Rule, once all of the data is received and analyzed. However, regardless of the back and forth between Entergy and NYSDEC on Entergy's FOIL request, all of the NYSDEC tracking data should be readily available to NMFS for its review in the course of developing any Final Rule.

[16] *See* Biological Information Document at 5 (*citing* Ryder, 1888; Dees, 1961; Vladykov and Greeley, 1963; Scott and Crossman, 1973; Gilbert, 1989; Smith and Clugston, 1997; Bain *et al.* 2000; Collins *et al.*, 2000; Caron *et al.*, 2002; Hatin *et al.*, 2002; Mohler, 2003; Greene *et al.*, 2009; Balazik *et al.* 2012; Hager *et al.* 2014).

[17] Indian Point BiOp/ITS at 42*; see also* Tappan Zee Bridge Replacement Biological Opinion (June 20, 2016) ("TZ BiOp/ITS") at 50; Biological Information Document at 11.

Moreover, larval Atlantic sturgeon are assumed to inhabit the same areas where they were spawned and live at or near the bottom.[18] Consequently, larval habitat is appropriately considered coincident with spawning habitat.[19]

None of those identified areas are near Indian Point. Indian Point is located at river kilometer ("rkm") 69 (*i.e.*, 69 kilometers upstream of the mouth of the river), It does not possess the requisite substrate and is not close enough to known spawning areas to reasonably support early life stages of Atlantic sturgeon. In other words, the well-documented spawning sites with the physical features essential to Atlantic sturgeon reproduction, egg and larval growth are well north of and distinct from Indian Point. This conclusion is confirmed by the HRBMP data summarized in Attachment A and Indian Point's historic entrainment studies.[20]

NMFS knows as much. In the Indian Point BiOp/ITS, NMFS records that Indian Point has never entrained an Atlantic sturgeon, nor would it be expected to, based on its distance from spawning grounds and habitat characteristics:

> Given the distance between the intake and the deep channel (2,000 feet; 610 meters) where any larvae would be present if in the action area, larvae are unlikely to occur near the intake where they could be susceptible to entrainment. No Atlantic sturgeon larvae have been documented as entrained at IP2 and IP3. The nearest documentation of Atlantic sturgeon larvae to IP2 and IP3 is at the Danskammer facility, approximately 23 miles upstream. Based on the life history of Atlantic sturgeon, the location of spawning grounds within the Hudson River, and the patterns of movement for eggs and larvae, it is extremely unlikely that any Atlantic sturgeon early life stages would be entrained at IP2 and/or IP3.[21]

For these reasons, there is no question that the Indian Point Vicinity is not "critical habitat" for sturgeon spawning or early life stages. Based on the above, the Indian Point Vicinity, which is conservatively defined as the area within 1000 feet (300 meters) north, south and west of Indian Point, should be excluded from the Final Rule.

Juvenile Sturgeon

The Hudson River habitats where juvenile sturgeon congregate in the Hudson are equally well known and understood:

> Based on river-bottom sediment maps (Coch, 1986) most juvenile sturgeon habitats in the Hudson River have clay, sand, and silt substrates (Bain et al., 2000). Newburgh and Haverstraw Bays in the Hudson River are areas of known juvenile sturgeon

[18] *See, e.g.,* Biological Information Document at 5 (Ryder, 1888; Smith *et al.*, 1980; Bain *et al.*, 2000; Kynard and Horgan, 2002; Greene *et al.*, 2009); 81 Fed. Reg. at 35703 (summarizing peer-reviewed, published science supporting yolk sac and post yolk sac larvae at the bottom of the water column).

[19] *Id.*

[20] *See, e.g.,* HRBMP Annual Reports (reflecting no Atlantic sturgeon eggs or larvae in the Indian Point Region); 1976-1981, 1983-1987 Indian Point Entrainment Abundance Sampling (reflecting no entrainment of Atlantic sturgeon eggs or larvae).

[21] Indian Point BiOp/ITS at 60.

> concentrations (Sweka et al., 2007). Sampling in spring and fall revealed that highest catches of juvenile Atlantic sturgeon occurred during spring in soft-deep areas of Haverstraw Bay even though this habitat type comprised only 25% of the available habitat in the Bay (Sweka et al., 2007). Overall, 90% of the total 562 individual juvenile Atlantic sturgeon captured during the course of this study ... came from Haverstraw Bay (Sweka et al., 2007).[22]

Haverstraw Bay spans rkm 58 to 66, three kilometers south of Indian Point even at its closet point. Newburgh Bay is located at rkm 105, well north of Indian Point. Consequently, the known habitats for juvenile sturgeon, with the habitat markers that support juvenile growth, are not located in the Indian Point Vicinity. This conclusion is confirmed, again doubly, by the HRBMP data reflected in Attachment A and the NYSDEC sturgeon tracking data for 2012-2013 represented in Attachment B. Both Attachments reflect no presence of juvenile Atlantic sturgeon in the Indian Point Vicinity, particularly as compared to Haverstraw Bay, over the most recent fifteen years of River-wide monitoring and despite two intensive years of sturgeon tagging.

Further, and as reflected in the excerpts from the Indian Point BiOp/ITS and TZ BiOp/ITS quoted above, NMFS knows as much.[23]

For these reasons, there is no question that the Indian Point Vicinity is not "critical habitat" for juvenile sturgeon. Again, and based on the above, the Indian Point Vicinity, which is conservatively defined as the area within 1000 feet (300 meters) north, south and west of Indian Point, should be excluded from the Final Rule.

Adult Sturgeon

At approximately age 3, Hudson River juveniles begin to migrate to marine waters where they become mature adults and are recruited to the population. *See id.; see also* Biological Information Document at 6. For those juveniles in Haverstraw Bay south of Indian Point, this migration south toward the mouth of the Hudson will never take them by or through the Indian Point Vicinity. For those juveniles north of Indian Point, their preferred passage is in the deep channel, which NMFS has recognized is located more than 600 meters from Indian Point. *See, e.g.,* Attachment B (reflecting as much for juvenile Atlantic sturgeon). At most, migrating sturgeon headed for the Atlantic may stray from their preferred and customary passage route through the deep channel to pass closer to Indian Point. Atypical passage, or straying, is not enough to constitute critical habitat, which by regulation "shall not include the entire geographical area which can be occupied by the threatened or endangered species," where the evidence is that is it nor preferred or suitable habitat for the species in question.[24]

For these reasons, there is no question that the Indian Point Vicinity is not "critical habitat" for migrating juvenile or adult sturgeon. Again and based on the above, the Indian Point Vicinity, which is conservatively defined as the area within 1000 feet (300 meters) north, south and west of Indian Point, should be excluded from the Final Rule.

Conclusion

---

[22] Indian Point BiOp/ITS at 42;*see also* TZ BiOp/ITS at 50-51 (same).

[23] Indian Point BiOp/ITS at 42; *see also* TZ BiOp/ITS at 50-51 (same).

[24] *See, e.g.,* 16 U.S.C. §1532(5)(C) (emphasis supplied); 81 Fed. Reg. 35702.

NMFS already has considered, in connection with the issuance of the Indian Point BiOP/ITS, key aspects of Atlantic sturgeon behavior and habitat use in the Indian Point Vicinity, which demonstrates that the areas within about 1,000 feet of Indian Point does not contain features essential to any life stage of Atlantic sturgeon. NMFS therefore could and should have used this information to more specifically delineate critical habitat in the Proposed Rule in accordance with this "best scientific data available," by not including the Indian Point Vicinity.

Based on this evidence, which represents the best scientific data available, we respectfully submit that NMFS cannot reasonably conclude that the Indian Point Vicinity is "essential to the conservation of the species."[25] Put another way, given the lack of any demonstrated importance of the Indian Point Vicinity to or usage of that Vicinity by Atlantic sturgeon, it is inconceivable that any federally-approved action within the small Indian Point Vicinity would ever rise to the level of "destruction or adverse modification" of critical habitat as the Services have defined it, which requires a demonstration that the action "negatively affects the value of the critical habitat *as a whole* for the conservation of the listed species."[26] Designating the Indian Point Vicinity as critical habitat would thus lead to additional consultations for no practical purpose. Accordingly, we respectfully submit that the critical habitat designation in the Proposed Rule should not include the Indian Point Vicinity.

B. The USCG-Created Indian Point Safety and Security Zone Should Be Excluded from the Critical Habitat Designation under Section 4(b)(2) of the ESA.

For the reasons given above, the Indian Point Vicinity should not qualify as critical habitat for the Atlantic sturgeon in the first instance, because it does not possess characteristics "essential to the conservation of the species." Even if the Vicinity did possess such characteristics, in designating critical habitat NMFS also must take into consideration "the economic impact, *the impact on national security,* and any other relevant impacts, of specifying any particular area as critical habitat."[27] The ESA then "provides the Secretary with broad discretion to exclude any area from critical habitat if the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless it is determined, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned."[28] The national security and economic circumstances implicated within Indian Point's safety and security zone – within which Entergy is the only inhabitant – warrant excluding the safety and security zone from the habitat designation, particularly when evaluated in connection with the absence of nearby habitat that is demonstrably "essential to the conservation of the species."

1. The Indian Point Safety and Security Zone

The Indian Point safety and security zone comprises that region of the Hudson River, as specifically delineated and established by 33 C.F.R. § 165.196(a)(1), within which the USCG supports the primacy of

---

[25] For the reasons detailed below, the Indian Point Vicinity is conservatively defined as the area within 1,000 feet (300 meters) north, south and west of Indian Point.

[26] Definition of Destruction or Adverse Modification of Critical Habitat, 81 Fed. Reg. 7214, 7218 (Feb. 11, 2016) (emphasis added); *see also id.* (definition is intended to "exclude those adverse effects on critical habitat that are so minor in nature *that they do not impact the conservation of a listed species*") (emphasis added).

[27] 16 U.S.C. § 1533(b)(2).

[28] 81 Fed. Reg. 35713.

Entergy's physical security and protection obligations. It encompasses a small area within a 300-yard radius of the Indian Point pier.[29] Entergy (and its contractors and similarly authorized visitors) is necessarily the only non-government entity present within the safety and security zone. The area covered by the safety and security zone is approximately 30 acres, or 0.7% of the surface area of the Hudson River within the seven mile stretch near Indian Point. *See* Attachment C ("Safety and Security Zone Relative to Indian Point Reach of the Hudson River (River Miles 39-46)"). With respect to the entire 154-mile portion of the Hudson River designated as critical habitat, the safety and security zone is a proverbial drop in the bucket.

The history of this zone's creation merits discussion, as it was a direct result of the terrorist attacks of September 11, 2001:

> On September 11, 2001, three commercial aircraft were hijacked and flown into the World Trade Center in New York City, and the Pentagon, inflicting catastrophic human casualties and property damage. National security and intelligence officials warn that future terrorist attacks are likely. The President has continued the national emergencies he declared following the September 11, 2001 terrorist attacks. The President also found pursuant to law, including the Magnuson Act, that the security of the United States is endangered by disturbances in international relations of [the] United States that have existed since the terrorist attacks on the United States and such disturbances continue to endanger such relations. Immediately following the September 11th attacks, we published a temporary final rule that established a temporary regulated navigation area, and safety and security zones in the New York Marine Inspection and Captain of the Port New York Zones. These measures were taken to safeguard human life, vessels and waterfront facilities from sabotage or terrorist acts. That temporary final rule was subsequently revised to extend its effective period through December 31, 2002. The Coast Guard is establishing permanent safety and security zones through the New York Marine Inspection and Captain of the Port Zones as part of a comprehensive, port security regime designed to safeguard human life, vessels and waterfront facilities from sabotage or terrorist acts.[30]

Within the zone, Entergy has an unequivocal legal obligation to take any and all necessary action to safeguard Indian Point and its nuclear materials, including via a physical security and protection program ensuring that Entergy at all times maintains its capabilities to detect, assess, interdict and neutralize threats.[31]

In sum, the safety and security zone provides a clear and appropriate delineation of that region of the Hudson River within which Entergy's and the USCG's safety and security obligations are paramount. Any NMFS determination or action that could be considered or construed to require disclosure of, limit or in any other way impede (including by pre-interdiction consultation) Entergy's or the USCG's actions or activities within this area potentially would conflict with the clear national directive to protect and secure our nuclear facilities. For example, Entergy is concerned that the need to consult with NMFS prior to making changes to security arrangements within the safety and security zone could potentially delay

---

[29] *See* 33 C.F.R. §165.169(a)(1) (designating as a safety and security zone "[a]ll waters of the Hudson River within a 300-yard radius of the [Indian Point] pier in approximately position 41°16'12.4" N, 73°57'16.2" W (NAD 83)").

[30] 68 Fed. Reg. 2887 (internal citations omitted).

[31] *See, e.g.*, 10 C.F.R. § 73.75(b).

implementation of changes deemed necessary in the future, or even require reconsideration of existing necessary security measures leading to uncertainty at the facility.

2. Energy Security and Climate Change Considerations

Whether considered as a national security issue, an economic issue, or as "any other relevant impact," NMFS also should take into account the economic and environmental benefits that Indian Point – a nuclear generating facility that provides more than 2,000 MW of generating capacity on a baseload basis, and the only entity in the safety and security zone – provides, when deciding whether to designate the safety and security zone as part of the critical habitat. These benefits should not be put at risk by unknown regulatory burdens and potential incremental restrictions on facility operations.

There is no doubt that energy security and the development of renewable energy resources are important national goals that can and should be considered by NMFS under Section 4(b)(2) when designating critical habitat. NMFS and the Fish and Wildlife Service ("FWS") previously have explained that "if the relevant Service determines in a particular designation that domestic energy security is a relevant impact of that designation, that Service will consider the impacts of designation on domestic energy security." Revisions to the Regulations for Impact Analyses of Critical Habitat, 78 Fed. Reg. 53058, 53070 (Aug. 28, 2013). Indeed, in Designation of Critical Habitat for Astragalus lentiginosus (Coachella Valley Milk-Vetch),[32] the FWS specifically carved out areas around wind projects on this basis. In that rulemaking, "commenters expressed concern that designating critical habitat on lands occupied by wind energy projects would conflict with Federal and California State policies aimed at promoting alternative energy by potentially introducing unknown regulatory burdens and restrictions on the operation of wind energy facilities."[33] The commenters also explained that "measures in place" already "provide protection for Astragalus lentiginosus var. coachellae." FWS responded, in relevant part, by stating that it would exclude the relevant areas from the critical habitat:

> The Secretary has the discretion to exclude an area from critical habitat under section 4(b)(2) of the Act after taking into consideration the economic impact, the impact on national security, and any other relevant impact if he determines that the benefits of such exclusion outweigh the benefits of designating such area as critical habitat, unless he determines that the exclusion would result in the extinction of the species concerned. In exercising his discretion to exclude areas from critical habitat under section 4(b)(2) of the Act, the Secretary weighed the benefits of exclusion against the benefits of inclusion, and is exercising his discretion to exclude all lands covered under the Coachella Valley MSHCP/NCCP from this final revised critical habitat designation ... Any lands covered under the Coachella Valley MSHCP/NCCP containing wind power facilities are, therefore, excluded from this critical habitat designation.[34]

Baseload nuclear power, even more so than intermittent wind power, is of vital importance to energy security and the fight against global climate change, as recognized at the state and federal levels. President Obama included the reinvigoration of the nuclear industry as an explicit component of his

---

[32] 78 Fed. Reg. 10450 (Feb. 13, 2013).

[33] *Id.* at 10483.

[34] *Id.* at 10484.

national energy and security strategy.[35] Nuclear power continues to contribute almost 20% of the electricity generated in the United States, which reduces America's dependence on foreign oil and diversifies its energy sources and suppliers.[36] The United States Global Change Research Program also has described the role that nuclear energy plays in the urgent need to address climate change.[37] On August 3, 2015, President Obama and the Environmental Protection Agency announced the Clean Power Plan, which "shows the world that the United States is committed to leading global efforts to address climate change" by reducing carbon emissions by 2030.[38] The Clean Power Plan specifically cites "increased nuclear generation" as a measure for achieving emission reduction goals.[39] When adopting a Clean Energy Standard just one month ago, New York State recognized that "losing the carbon-free attributes of [nuclear power] generation before the development of new renewable resources between now and 2030[] would undoubtedly result in significantly increased air emissions due to heavier reliance on existing fossil-fueled plants or the construction of new gas plants to replace the supplanted energy."[40]

Indian Point, a more than 2,000 MW, baseload nuclear generation facility located in supply-constrained Southeastern New York, plays a particularly significant role with respect to energy security and in the fight against climate change. Due to its size and form of generation technology, Indian Point generates more electrical energy than any other facility within New York State.[41] Electricity generated by Indian Point accounts for approximately 10 percent of the total electricity consumption in New York State and 17 percent of the total electricity consumption in the Southeastern New York area. Indeed, when considering the New York City area alone (excluding the Long Island area and the Lower Hudson Valley), "[Indian Point] provides up to 30 percent of the New York City area's base-load electricity."[42] As in the Astragalus lentiginosus critical habitat designation, the economic and environmental benefits Indian Point provides should be considered in establishing the critical habitat boundaries.

3. The Benefits of Excluding the Indian Point Safety and Security Zone Outweigh the Benefits of Designating It

Based on the above, NMFS should exercise its discretion under Section 4(b)(2) to exclude the Indian Point safety and security zone from the critical habitat designation, as the benefits of doing so outweigh

---

[35] The White House, *National Security Strategy* (May 2010), at 30, 47.

[36] The White House National Economic Council, *Advanced Energy Initiative* (February, 2006) at 11 ("Nuclear power is also domestic and provides energy security....").

[37] U.S. Global Change Research Program, *U.S. National Climate Assessment: Climate Change Impacts in the United States* (May 2014) 7, 654.

[38] EPA, *Fact Sheet: Clean Power Plan and the Role of States,* https://www.epa.gov/sites/production/files/2015-08/documents/fs-cpp-states-decide.pdf (last visited August 25, 2016).

[39] *Id.*

[40] State of New York Public Service Commission, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard* (Aug. 1, 2016) at 19, *available at* http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B1A8C4DCA-E2CC-449C-AA0D-7F9C3125F8A5%7D.

[41] *See* 2014 NYISO Gold Book at 37 (Table III-2).

[42] *See* Manhattan Institute, Center for Energy Policy and the Environment, *The Economic Impacts of Closing and Replacing the Indian Point Energy Center* (Sept. 2012) at 2.

the benefits of including the zone within the habitat designation, and excluding the zone will not result in the extinction of the NYB DPS of the Atlantic sturgeon.

First, the benefits of including the Indian Point safety and security zone within the habitat designation are questionable at best, and certainly minor. As discussed above, the physical features of the Hudson in the vicinity of Indian Point are not consistent with those NFMS has identified as essential to reproduction and recruitment of the species. That is particularly true with respect to the safety and security zone. The zone extends at its widest only 300 yards from the eastern shore of the Hudson. As NMFS previously has noted, the deep water channel that adult Atlantic sturgeon use to transit the stretch of the Hudson River near Indian Point is more than 600 meters from the eastern shore, more than twice again the breadth of the safety and security zone. Unsurprisingly, therefore, the best scientific evidence – the tracking data discussed above – confirms that sturgeon are not expected to be found within the Indian Point safety and security zone.[43]

Second, the extent of the area that would be excluded – as reflected in Attachment ___ -- represent a fraction of a fraction of a percent of the Hudson River from New York City through the Troy Dam – is miniscule within the context of the designated habitat, and an area not used by Atlantic sturgeon. NMFS previously has taken this factor into account in excluding an even more significant extent of territory from a critical habitat designation on the basis of national security. *See, e.g.*, Designation of Critical Habitat for the Puget Sound/Georgia Basin Distinct Population Segments of Yellow Eye Rockfish, Canary Rockfish and Boccaccio, 79 Fed. Reg. 68042, 68070 (Nov. 13, 2014) (excluding areas representing 6-8% of the habitat on the basis of national security, and observing that this was a "small" area to exclude).

Third, the incremental benefits of the exclusion are further minimal in light of existing protections for aquatic species, including Atlantic sturgeon both directly and indirectly, within the safety and security zone. Indian Point – necessarily, the only entity within the safety and security zone – already operates pursuant to an existing, administratively-continued state pollution discharge elimination system ("SPDES") permit issued pursuant to Section 402 of the federal Clean Water Act ("CWA"), a permit that will be renewed by a final decision of NYSDEC after completion of a pending proceeding. Consistent with its existing SPDES permit, Indian Point already operates a state-of-the-art optimized Ristroph screen and fish handling and return system that EPA and NYSDEC consider the "best technology available" to reduce impingement. As a consequence, it is fair to say that the safety and security zone is already heavily regulated, including with respect to issues – thermal and other pollutant discharges, and water intakes – that theoretically could be relevant to sturgeon. Including the safety and security zone within the critical habitat designation will add little but more process to those existing protections. *Cf.* 79 Fed. Reg. at 68070 (noting that the Navy already provides protections to rockfish habitat within the excluded areas).

Fourth, there are clear benefits to excluding the safety and security zone from the critical habitat designation, which easily outweigh the benefits – if any – of including it. *See supra* at 10-13.

---

[43] As NMFS has consistently acknowledged, no entrainment occurs and impingement of adult Atlantic sturgeon is merely the collection of moribund or dead fish, the impacts to which are not attributable to Indian Point, and therefore cannot reasonably be attributed to the activities within the Indian Point safety and security zone. *See, e.g.*, Indian Point BiOp/ITS, at 82-83. Impingement of juveniles, if it occurs, is predicted to be extremely rare. Such impingement also results in no mortality, thanks to the Indian Point state-of-the-art fish handling and return system. The cause of such impingement, moreover, is being investigated to determine whether it is the same as the reason for adult sturgeon, *i.e.*, whether it results because the juvenile Atlantic sturgeon in question are already compromised by impacts not reasonably attributable to Indian Point. *Id.*

Finally, and for the reasons given above, there can be no credible argument that excluding the small safety and security zone from the critical habitat designation will result in "extinction" of the NYB DPS of the Atlantic sturgeon. In short, based on the above, NMFS should exercise its discretion to exclude the Indian Point safety and security zone from the critical habitat designation pursuant to Section 4(b)(2) of the ESA.

II. The Proposed Rule, As It Relates to the NYB DPS, Is Not Based on the Best Scientific Data Available

As noted in Section I above, the ESA requires that a critical habitat designation be both specific and based on the "best scientific data available ... ." for the NYB DPS. 16 U.S.C. § 1533(b)(2).[44] The failure to appropriately specify, and to consider the best scientific data available in that specification, renders the designation of critical habitat invalid. *See, e.g., Bennett v. Spear*, 520 U.S. 154, 172 (1997) ("[t]he terms of § 1533(b)(2) are plainly those of obligation, rather than discretion ... ."); *Middle Rio Grande Conservancy Dist. v. Babbitt*, 206 F.Supp.2d 1156 (D. New Mexico 2000) (critical habitat designation set aside where, among other things, designation was based on incomplete and untimely information).

The Proposed Rule fails to take into account, or even identify on a consistent basis, the best available scientific evidence – that is, the available, substantive data and analysis about the preferred habitat for sturgeon within the Hudson River, as represented by Attachments A and B. NMFS' failure is doubly problematic. First, the sort of temporal and spatial information about Atlantic sturgeon contained within Attachments A and B represents just the sort of operative information necessary and appropriate for a critical habitat determination, because it reveals the habitat actually used (and, in the absence of identified barriers, that which could be used) by Atlantic sturgeon, including during migration. Second, NMFS has failed to take account of this information, despite the fact that it is both known and readily available to NMFS.

That the information is known and available to NMFS is established in multiple ways. Outside of the Proposed Rule, NMFS has conceded that "[t]he Hudson River population of shortnose and Atlantic sturgeon have been the focus of a prolonged history of scientific research." TZ BiOp/ITS at 51. Likewise, although in the TZ BiOp/ITS NMFS records its authorization of (and an allowed sturgeon mortality associated with) the then-pending NYSDEC surveys of the temporal and spatial distribution patterns of Atlantic sturgeon, as reflected in Attachment B, it never mentions the results of those studies – the data and information that they provide – in issuing the Proposed Rule. *Id.* at 51-52. To be clear, the TZ BiOP/ITS records the following studies:

> NYSDEC holds a scientific research permit (#16439, which replaces their previously held permit #1547) authorizing the assessment of habitat use, population abundance, reproduction, recruitment, age and growth, *temporal and spatial distribution,* diet selectivity, and contaminant load of shortnose sturgeon in the Hudson River Estuary from New York Harbor (RKM 0) to Troy Dam (RKM 245). NYSDEC is authorized to use gillnets and trawls to capture up to 240 and 2,340 shortnose sturgeon [sic] in year one through years three and four and five, respectively. Research activities include: capture; measure, weigh; tag with passive integrated transponder (PIT) tags and Floy tags, if untagged; and sample genetic fin clips. A first subset of fish will also be anesthetized

[44] Entergy takes no position on any critical habitat designation, other than the NYB DPS.

> and tagged with acoustic transmitters; a second subset will have fin rays sampled for age and growth analysis; and a third subset will have gastric contents lavaged for diet analysis, as well as blood samples taken for contaminants. ... This permit expires on November 24, 2016.
>
> In April 2012, NYSDEC was issued a scientific research permit (#16436) which authorizes the *capture, handling and tagging of Atlantic sturgeon in the Hudson River.* NYSDEC is authorized to capture 1,350 juveniles and 200 adults. The unintentional mortality of two juveniles is anticipated annually over the five year life of the permit. This permit expires on April 5, 2017.
>
> A permit was issued to Dynegy in 2007 (#1580, originally issued as #1254) to evaluate the life history, population trends, *and spacio-temporal and size distribution of shortnose sturgeon collected during the annual Hudson River Biological Monitoring Program.* This permit was reissued to Entergy in August 2012 as permit #17095; the permit will expire in 2017. The permitholders are authorized to capture up to 82 shortnose sturgeon adults/juveniles and 82 Atlantic sturgeon annually to measure, weigh, tag, photograph, and collect tissue samples for genetic analyses.[45]

None of these studies, nor the directly relevant information that they provide on the locations of nearly 5,000 tagged sturgeon within the Hudson River over a multi-year period, is referenced in the Proposed Rule. Nor is the HRBMP data reflected in Attachment A, which NMFS has not requested from Entergy, NAI or ASA. Had NMFS considered the data in Attachments A and B, as summarized in Section I above, it could have specified the critical habitat within the Hudson, as applicable law requires. *See* Section I, above (summarizing the legal standard). NMFS certainly would have known that the Indian Point Vicinity does not meet the definition of critical habitat, and therefore should not be included in the Final Rule.

Even without the data summarized in Attachments A and B, NMFS could have reached a more accurate, more specific critical habitat determination for the NYB DPS, based on the peer-reviewed, published science. For instance, critical habitat should reflect well-documented Atlantic sturgeon habitat preferences, which would warrant a focus on bottom habitat in the Hudson, particularly the deep channel, not the entire water column on a bank-to-bank basis. This is because, as the best scientific data available indicates, during all relevant life stages, Atlantic sturgeon are demersal and "depend *almost exclusively* on benthic substrates and bottom waters for spawning, feeding, migration, and refuge from predation or stressful environments (e.g., flow and temperature *refugia*)."[46]

Likewise, in terms of critical habitat conditions, the Proposed Rule highlights temperature information in a manner that translates to a less correct, less effective Proposed Rule. First, the dated 1984 treatise on which the Proposed Rule relies was about shortnose, not Atlantic sturgeon, and includes no operative

---

[45] TZ BiOp/ITS, p. 51-52 (emphasis added).

[46] Secor, D.H. and Niklitschek, E.J., Sensitivity of sturgeons to environmental hypoxia: A review of physiological and ecological evidence, in Thurston, R.V. (ED.), Fish Physiology, Toxicology and Water Quality, Proceedings of the Sixth International Symposium, La Pax, Mexico, 22-26 Jan. 2001 (emphasis added) (citations omitted); *see also* 81 Fed. Reg. at 35703 (acknowledging same).

temperature limit.[47] Second, substantial recent work by Niklitschek and Secor establishes that hypoxia drives the viability of Atlantic sturgeon habitat (and therefore presumptively habitat designation), with tertiary (after salinity) effects from temperature.[48] In these scientists' own words: "[T]his limited ability to adapt to hypoxia could explain the lack of recovery observed for sturgeon populations inhabitating heavily eutrophied estuaries along the East coast of the United States."[49] The only temperature-determinate analysis that we have identified, *i.e.*, where temperature alone was evaluated in a manner that it could be effectively disaggregated, is a laboratory study of sixteen (16) juvenile Atlantic sturgeon from New Brunswick, Canada performed by Spear and Kieffer, who identified 30.9 +/- 0.31°C (*i.e.*, 87-88°F +/-°) as the "ecologically and physiologically valuable reference point than can signal an early sign of thermal stress," while as importantly establishing that oxygen-carrying capacity was unaffected at this temperature.[50] Whether the single Spear and Kieffer study of Atlantic sturgeon from a far cooler Canadian location is relevant for Atlantic sturgeon in the NYS DPS is far from clear, given well documented increasing temperature tolerances for southerly populations; in any event, even that study does not reasonably support a habitat designation for juvenile Atlantic sturgeon in the NYB DPS based on temperatures below 30.9 C° +/- 0.31C°.

Based on this peer-reviewed, published scientific information, the critical habitat designation in the Proposed Rule should be amended to identify adequate oxygenation (above hypoxia, defined as 40% oxygen saturation) as an operative "psychical or biological feature" to Atlantic sturgeon critical habitat when the condition is natural, underscoring, as NMFS acknowledges, that hypoxia impacts can be severe for Atlantic sturgeon, *i.e.*, impairing otherwise available sturgeon habitat.[51] To that end, and entirely

---

[47] *See* Dadswell, M. J. et al., Synopsis of Biological data on Shortnose Sturgeon Acipenser brevirostrum, NOAA Technical Report, NMFS 14 (October 1984) (addressing shortnose sturgeon and reflecting frequent capture at up to 30 C).

[48] *See, e.g.,* Niklitschek, E.J. and Secor, D.H., Dissolved oxygen temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon I estuarine waters: I. Laboratory results, Jl. Exo. Marine Bio. & Ec., 381, S150-160, s157 (2009) ("*While low to nil mortality was observed at 100 DOsat, regardless of the corresponding salinity or temperature treatment*, it increased sharply at hypoxic conditions.") and s159 ("Under this scenario the limiting effects of hypoxia would reduce physiological scopes to a point where the relative importance of salinity effects becomes critical.") (emphasis added); Niklitschek, E.J. and Secor, D.H., Experimental and field evidence of behavioral habitat selection by juvenile Atlantic Acipenser oxyrinchus oxyrinchus and shortnose Acipenser brevirostrum sturgeon,, Jl. Fish Bio. 77, 1293-1308, 1302 (2010) (Table III, showing the primacy of dissolved oxygen (%), the secondary driver of salinity and the tertiary implications of both temperature extremes, under the evaluated oxygen saturation and salinity conditions, but also showing presence in the environment of Atlantic sturgeon at 28C and a tendency of shortnose sturgeon to prefer higher temperatures). Indeed, extensive assessment of Southern estuaries from which Atlantic sturgeon have been effectively extirpated demonstrates that any critical habitat assessment that fails to control, fishing mortality and hypoxia, is not grounded in sound science. Collins, M.R., et all, Primary factors affecting sturgeon populations in the Southeasterm United States: fishing mortality and degradation of essential habitats, Bull. Mar. Sci. 66:917-928 (2000).

[49] Niklitschek, E.J. and Secor, D.H., Dissolved oxygen temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon I estuarine waters: I. Laboratory results, Jl. Exo. Marine Bio. & Ec., 381, S150-160, s158 (2009) (citation omitted).

[50] *See* Spear, M.C., et al., Critical thermal maxima and hematology for juvenile Atlantic (Acipenser oxyrinchus Mitchill, 1815) and shortnose (Acipenser brevirostrum Lesueur, 1818) sturgeons, J. Appl. Icthyol. 21:251-257 (2016); *but see* 81 Fed. Reg. at 35708 (mistakenly identifying 30 C for juvenile rearing habitat).

[51] *See, e.g.,* Niklitschek, E.J. and Secor, D.H., Dissolved oxygen temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon I estuarine waters: I. Laboratory results, Jl. Exo. Marine Bio. & Ec., 381, S150-160 (2009) (particularly susceptibility of Atlantic strugeon); Niklitschek, E.J. and Secor,

missing from the Proposed Rule, is serious consideration of the dominant, well-documented (including by the National Research Council and NOAA) anthropogenic source of reduced oxygenation in the Hudson River – nutrient loading as a function of nitrogen and phosphorous inputs.[52] The failure to provide operative oxygenation levels where naturally occurring, e.g., as a function of salinity fronts, and also to highlight the sources of anthropogenic nutrient loading capable of being redressed through consultation or communicated to states for supportive action, for a species particularly susceptible to hypoxia, calls into question the basic science underpinning the Proposed Rule.[53] Indeed, NMFS' consideration of the best scientific data available would have allowed it to focus more effectively on particular areas where anthropogenic hypoxia could pose a threat to Atlantic sturgeon recovery, *e.g.*, consistent with evidence that past management of such conditions transformed the Hudson River shortnose sturgeon nursery habitat and supported that species' recovery.[54]

D.H., Experimental and field evidence of behavioral habitat selection by juvenile Atlantic Acipenser oxyrinchus oxyrinchus and shortnose Acipenser brevirostrum sturgeon,, Jl. Fish Bio. 77, 1293-1308 (2010) (same); 81 Fed. Reg. at 35708 ("… Atlantic sturgeon are particularly sensitive to low oxygen levels … .").

[52] *See, e.g.,* 81 Fed. Reg. at 33702 (""Accordingly, our step-wise approach for identifying potential critical habitat areas … include the following: Identify the physical and biological features essential to the conservation of the DPS and which may require special management considerations or protections … ."); National Academies of Science, National Research Council, *Clean Coastal Waters, Understanding and Reducing the Effects of Nutrient Pollution* (2000) (depicting the Hudson River as among the three river-dominated environments analyzed with the highest Nitrogen:Phosphorous ratios, and noting as well the failure to effectively gauge levels in substantial portions of the Hudson River); Bricker, S.B., et al., *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries,* NOAA, NOS, Special Projects Office and the National Centers for Coastal Ocean Science (1999) (identifying the extent and severity of nutrient pollution in the Hudson, characterizing it as moderately eutrophic) (updated in 2007); Howarth, R., et al., *Climatic control of eutrophication in the Hudson River Estuary,* Ecosystems in press (2000) (Hudson as moderately, but under certain circumstances likely to be exacerbated under Climate Change conditions highly, eutrophic); Howarth, R., et al., Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades, 31 Limn.& Oc. 364-376 (2006) ("Over the past two decades, a strong consensus has evolved among the scientific community that N is the primary cause of eutrophication in many coastal ecosystems … . Even though N is probably the major cause of eutrophication in most coastal systems in the temperate zone, optimal management of coastal eutrophication suggests controlling both N and P, in part because P can limit primary production in some systems."); Howarth. R., The Hudson Is the Most Heavily Nutrient-Loaded Estuary in the World: Should We Care?, Hudson River Foundation presentation (March 8, 2011) (showing that wastewater effluent continues to dominate Nitrogen and Phosphorous loading to the Hudson River estuary from the early 1970's to the mid-1990's, with atmospheric NOx deposition dominant in the upper Hudson, and wastewater treatment and nonpoint source discharges dominant in the lower Hudson); *see also* NAI, Technical Note on Analysis of Temperature and Dissolved Oxygen Trends from the Hudson River Biological Monitoring program 1974-2013 (8 August 2015) (Attachment D) (annual dissolved oxygen saturations from 1974 through 2013, with River-wide decreasing trends reflected in near-shore locations sampled in the HRBMP Beach Seine Survey).

[53] *See, e.g.,* 82 Fed. Reg. at 35709 (identifying an oxygenation level of 70% only for juvenile rearing habitat, and then stating that "[t]he specific oxygen concentration … values are provided as examples and guidance … .").

[54] *See, e.g.,* Secor, D.H. and Niklitschek, E.J., Sensitivity of sturgeons to environmental hypoxia: A Review of Physiological and Ecological Evidence, in Thurston, R.V. (ED.), Fish Physiology, Toxicology and Water Quality, Proceedings of the Sixth International Symposium, La Pax, Mexico, 22-26 Jan. 2001 (explaining the primacy of reducing hypoxia in the "Albany Pool" nursery habitat for shortnose sturgeon population recovery (at plus 400%), underscoring why focus on maintaining normoxia is warranted) (extensive citations omitted); Secor, D.H., Niklitschek, E.J. et al., Dispersal and growth of yearling Atlantic sturgeon, Acipenser oxyinchus, released into the Chesapeake Bay, Fish. Bull. 98:800-810 (2000) (reflecting effective extirpation and failed recovery in the Chesapeake, chiefly due to overfishing, bycatch and hypoxia, with limited indications of future success and no temperature-related limitations at 26.1 +/- 1.6 C°).

Based on the above, we respectfully request revision of the Proposed Rule to reflect the appropriate delineation of actual critical habitat in the Hudson River based upon the best scientific data available, including by excluding the Indian Point Vicinity, and by the inclusion (through emendation) of a focused discussion on hypoxia risks to, and associated habitat delineations for, Atlantic sturgeon.

III. No Further Consultation under the Proposed Rule Should be Required for Facilities Operating with a Current Incidental Take Statement.

Even if NMFS does not exclude the Indian Point safety and security zone or the Indian Point Vicinity more broadly from the designation of critical habitat, as it should, consultation under the Proposed Rule between NMFS and entities with a valid BiOp/ITS should not be required. Indian Point operates subject to, and with the benefit of, its BiOp/ITS, authorizing the limited take of shortnose and Atlantic sturgeon. The Indian Point BiOp/ITS followed an extensive consultation process among Entergy, the NRC and NMFS as part of the license renewal applications for Units 2 and 3 currently pending before the NRC. The Indian Point BiOp/ITS includes an evaluation of Indian Point's water withdrawals and thermal discharges, and concludes that Indian Point's continued operation is not likely to jeopardize the continued existence of either species. *See* Indian Point BiOP/ITS at 16 (defining the action area as the intake areas of Units 1, 2 and 3 and the region where the thermal plume extends into the Hudson River from IP2 and IP3) and 126 (no jeopardy determination). Moreover, as it relates to the Hudson River environment and the NYB DPS of Atlantic sturgeon, NMFS concluded as follows:

> The proposed action will have only insignificant effects on habitat and forage and will not impact the river in a way that makes additional growth of the population less likely, that is, will not reduce the river's carrying capacity. This is because impacts to forage will be insignificant and discountable and the area of the river that sturgeon will be precluded from (due to high temperatures) is small. The proposed action will not affect Atlantic sturgeon outside of the Hudson River or affect habitats outside of the Hudson River. Therefore, it will not affect estuarine or oceanic habitats that are important for sturgeon. Because it will not reduce the likelihood that the Hudson River population can recover, it will not reduce the likelihood that that NYB DPS as a whole can recover. Therefore, the proposed action will not appreciably reduce the likelihood that the NYB DPS of Atlantic sturgeon can be brought to the point at which they are no longer listed as endangered. Based on the analysis presented herein, the proposed action[] is not likely to appreciably reduce the survival and recovery of this species.[55]

Consequently, Entergy appreciates and could not agree more with NMFS' determination with respect to numerous sites that "no project modifications are projected to be required to address impacts solely to the proposed critical habitat."[56]. Entergy respectfully requests that NMFS conclude that further consultation under the Proposed Rule, should it become final, is not required for facilities such as Indian Point that hold a current BiOp/ITS that evaluated potential direct and habitat-related impacts to Atlantic sturgeon. Further consultation under these circumstances would simply consume limited agency resources to reach a conclusion already dictated by prior and comprehensive study.

[55] Indian Point BiOP/ITS at 125.

[56] 81 Fed. Reg. at 35713.

On behalf of Entergy, we appreciate your consideration of the these Comments and welcome your questions.

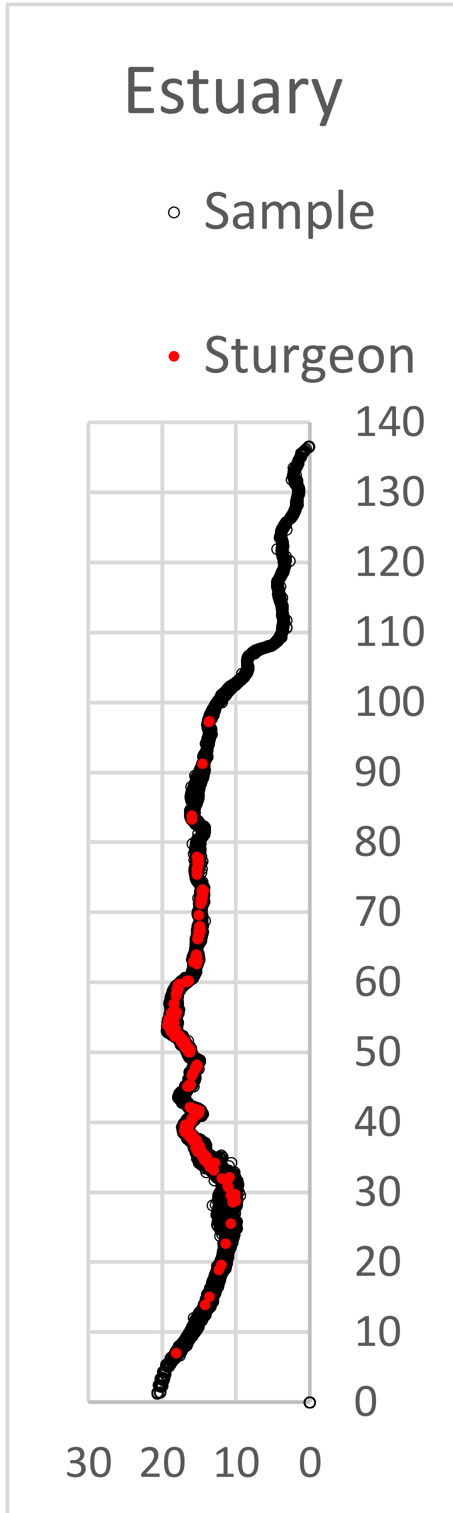
Sincerely,

Elise N. Zoli

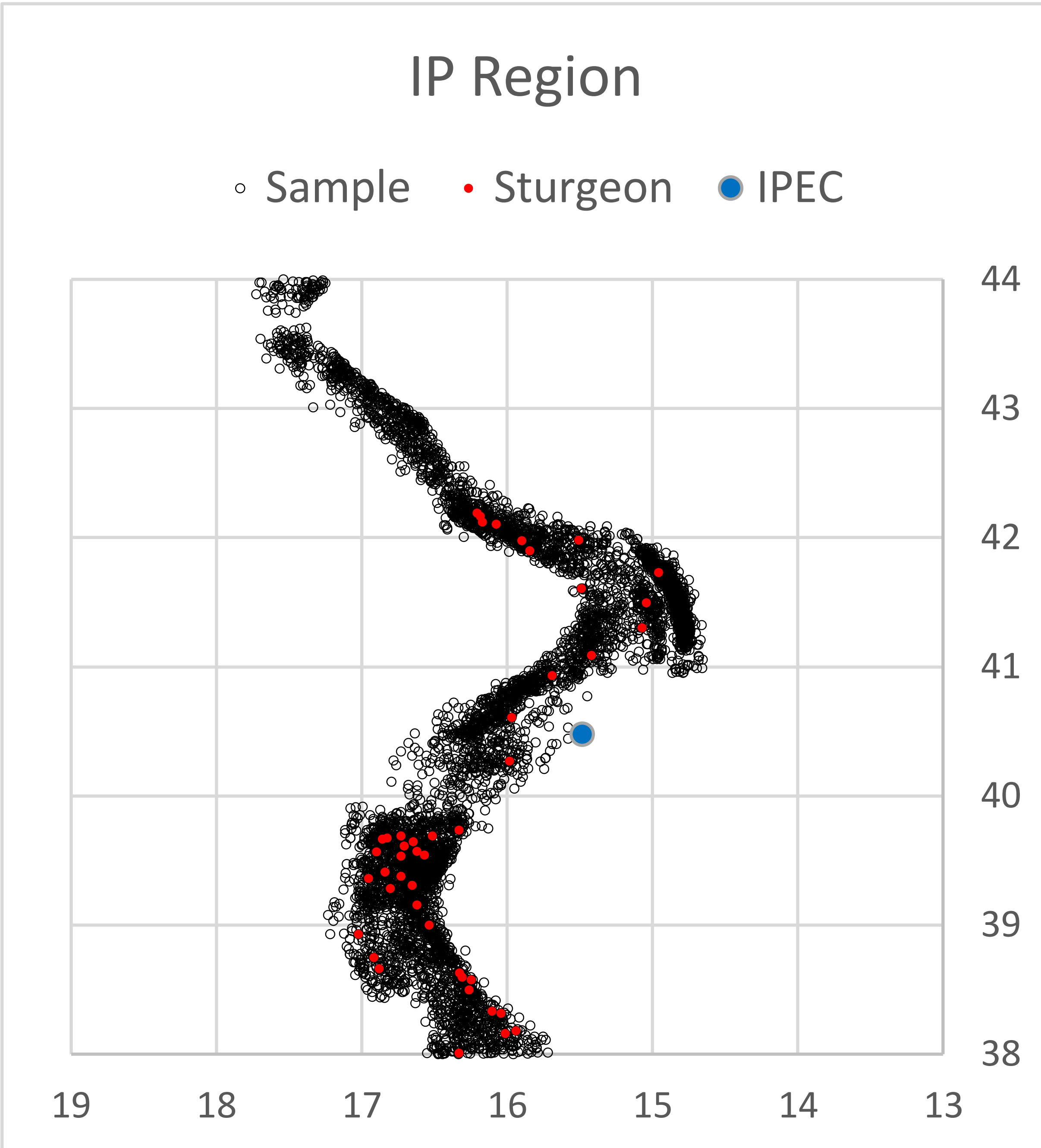
Enclosures

cc: Kelli M. Dowell, Assistant General Counsel, Environmental, Entergy Services, Inc.

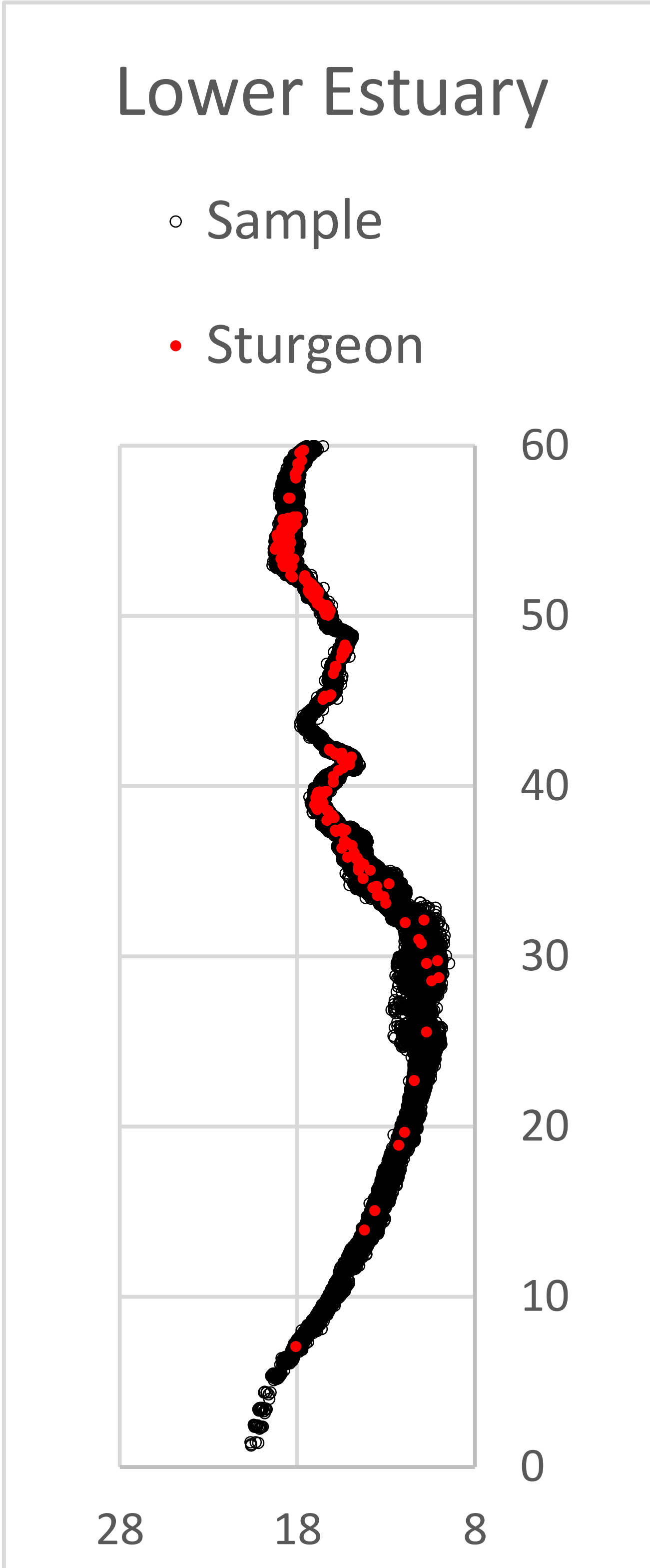
ATTACHMENT A



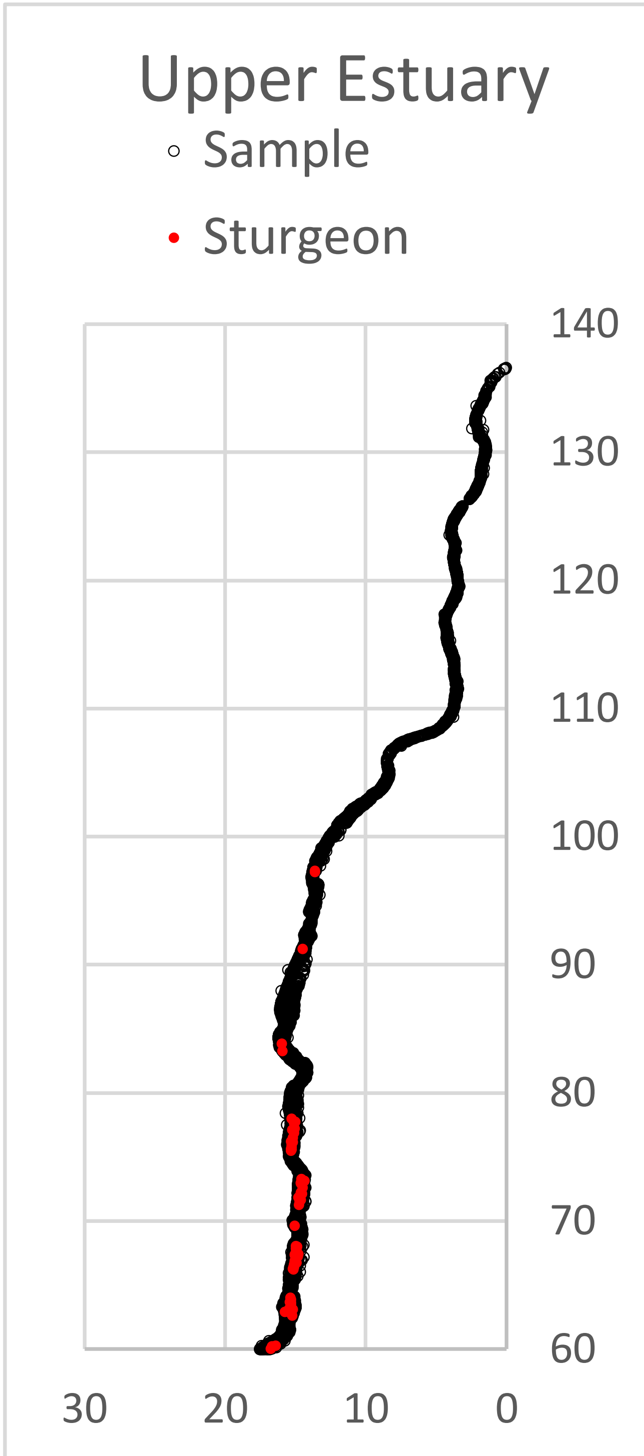
Plot of Hudson estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled, beam trawls, and Tucker trawls.



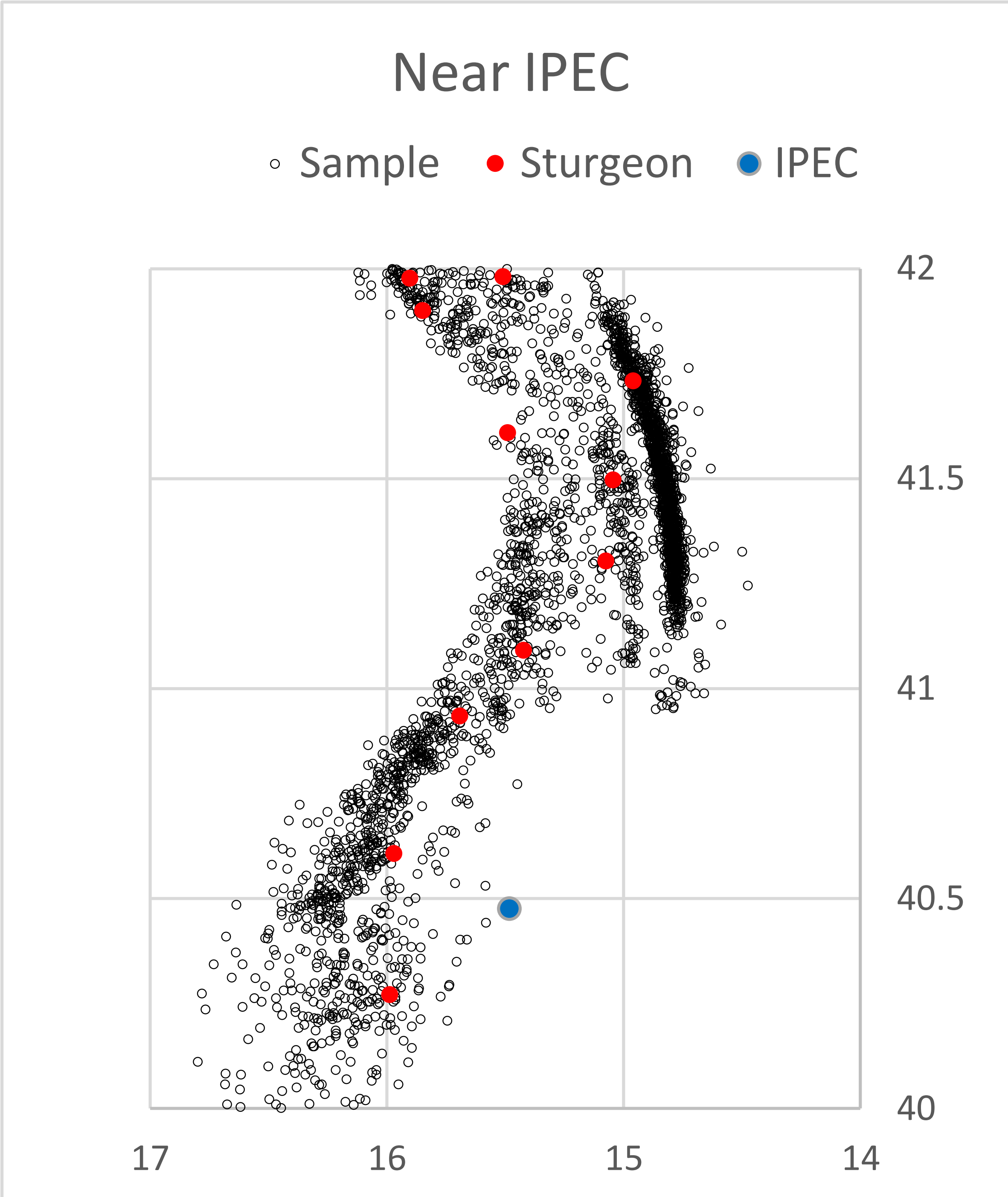
Plot of sampling locations within the Indian Point region and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled, beam trawls, and Tucker trawls.



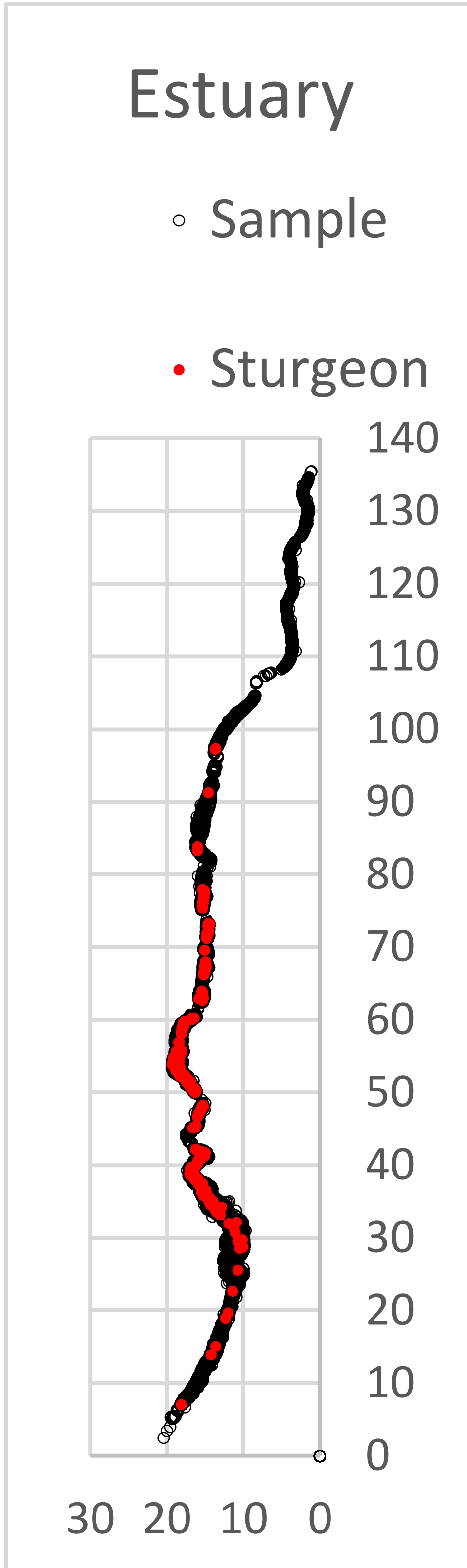
Plot of lower estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled, beam trawls, and Tucker trawls.



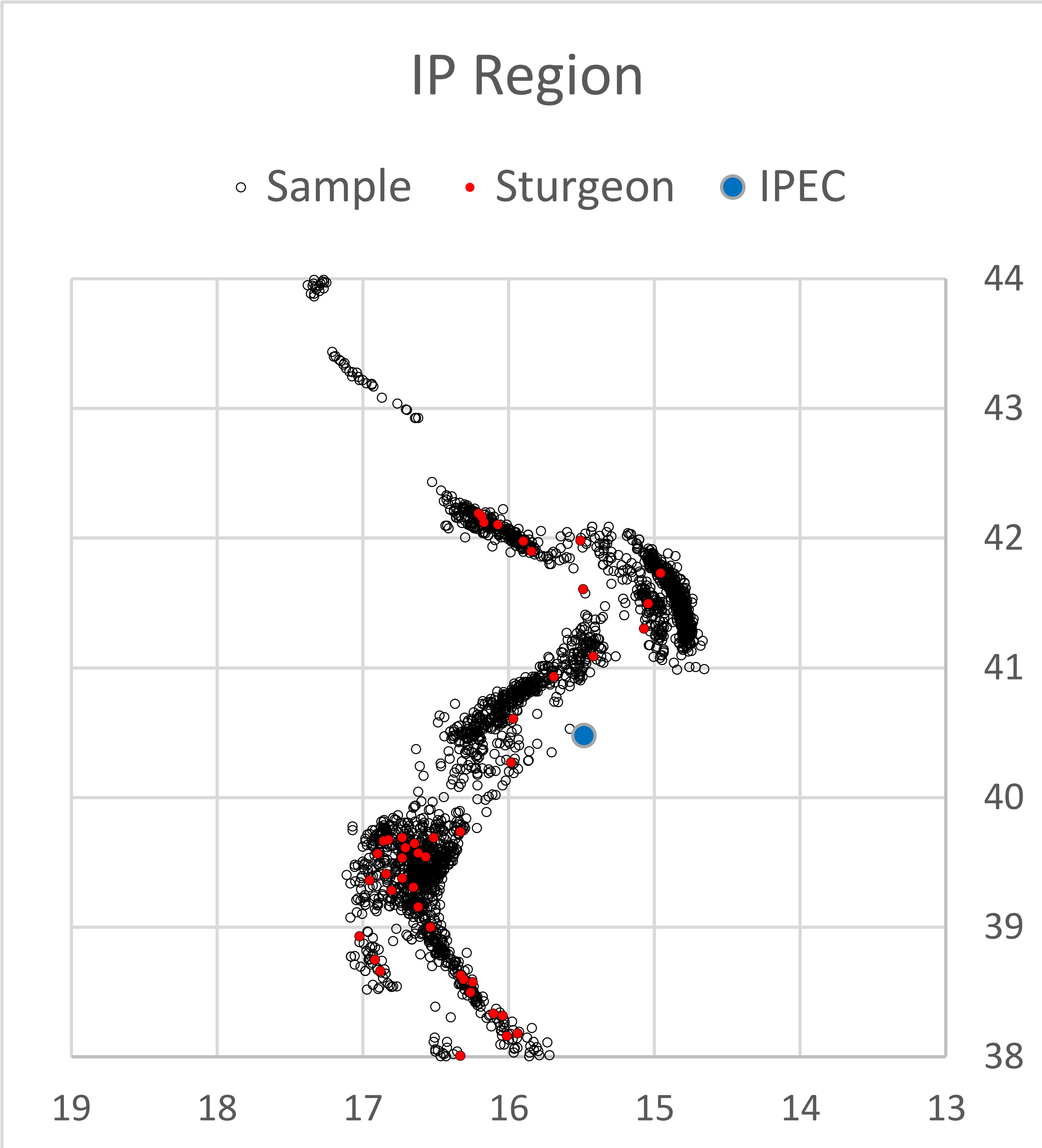
Plot of upper estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled, beam trawls, and Tucker trawls.



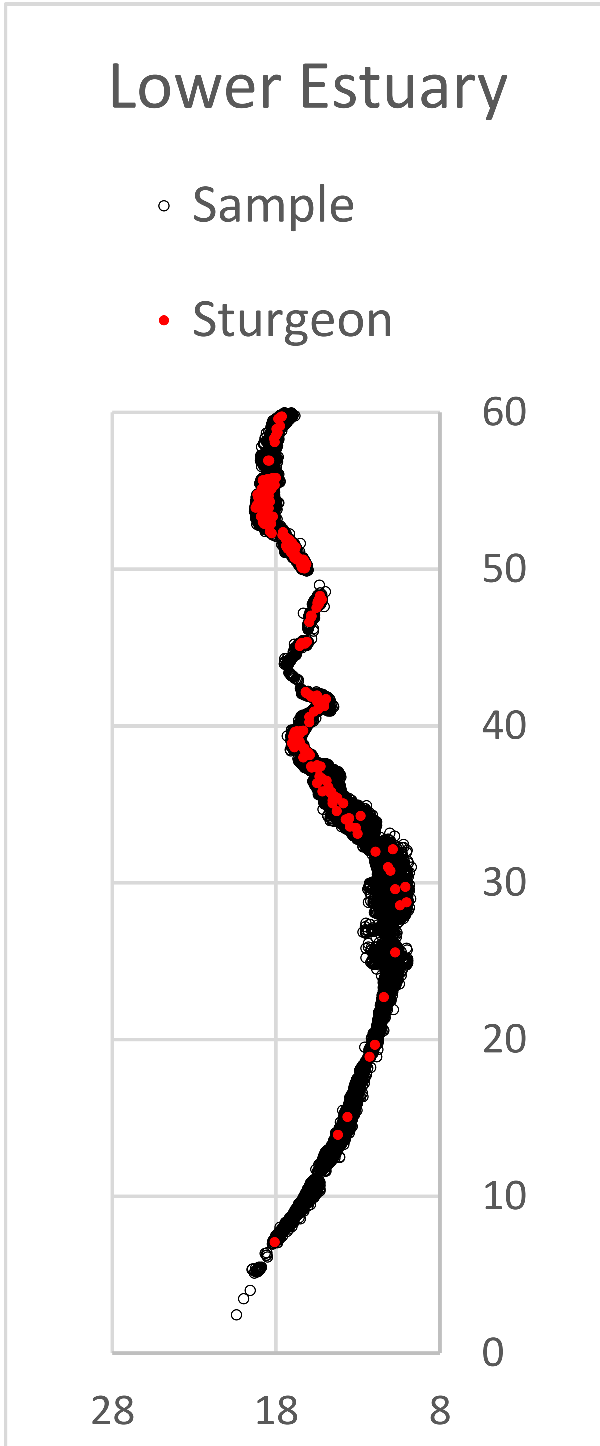
Plot of near IPEC sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled, beam trawls, and Tucker trawls.



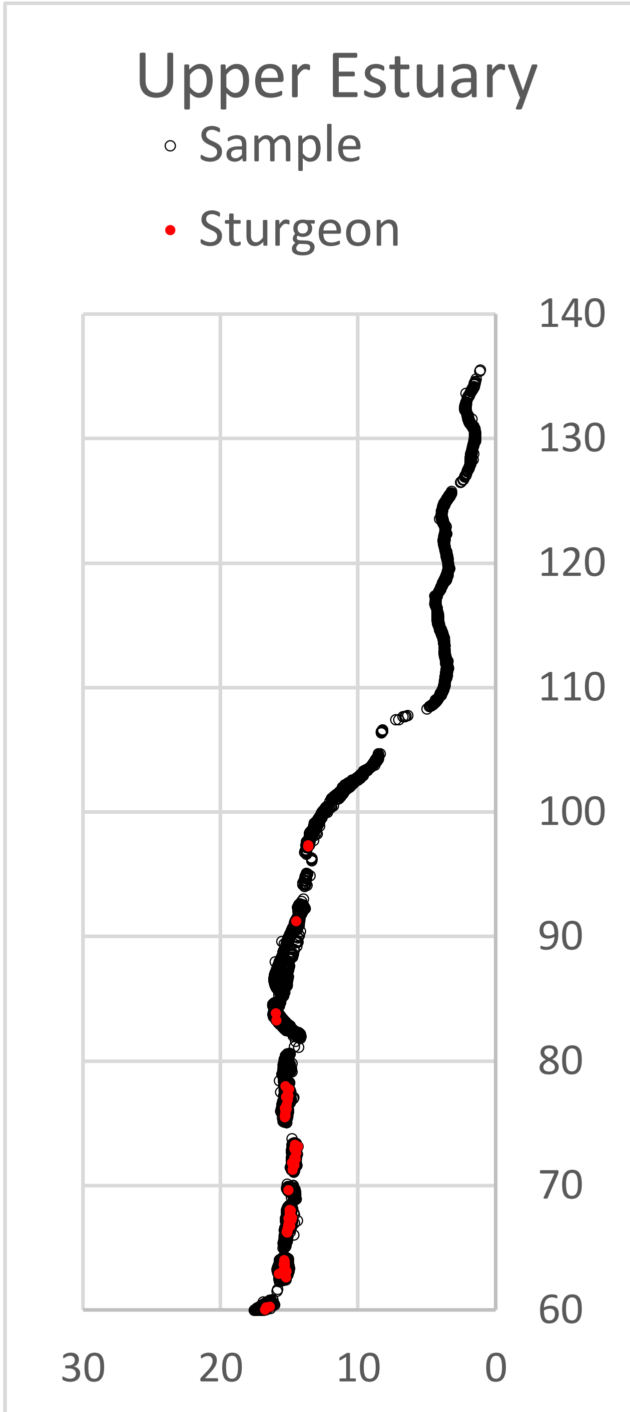
Plot of Hudson estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled and beam trawl.



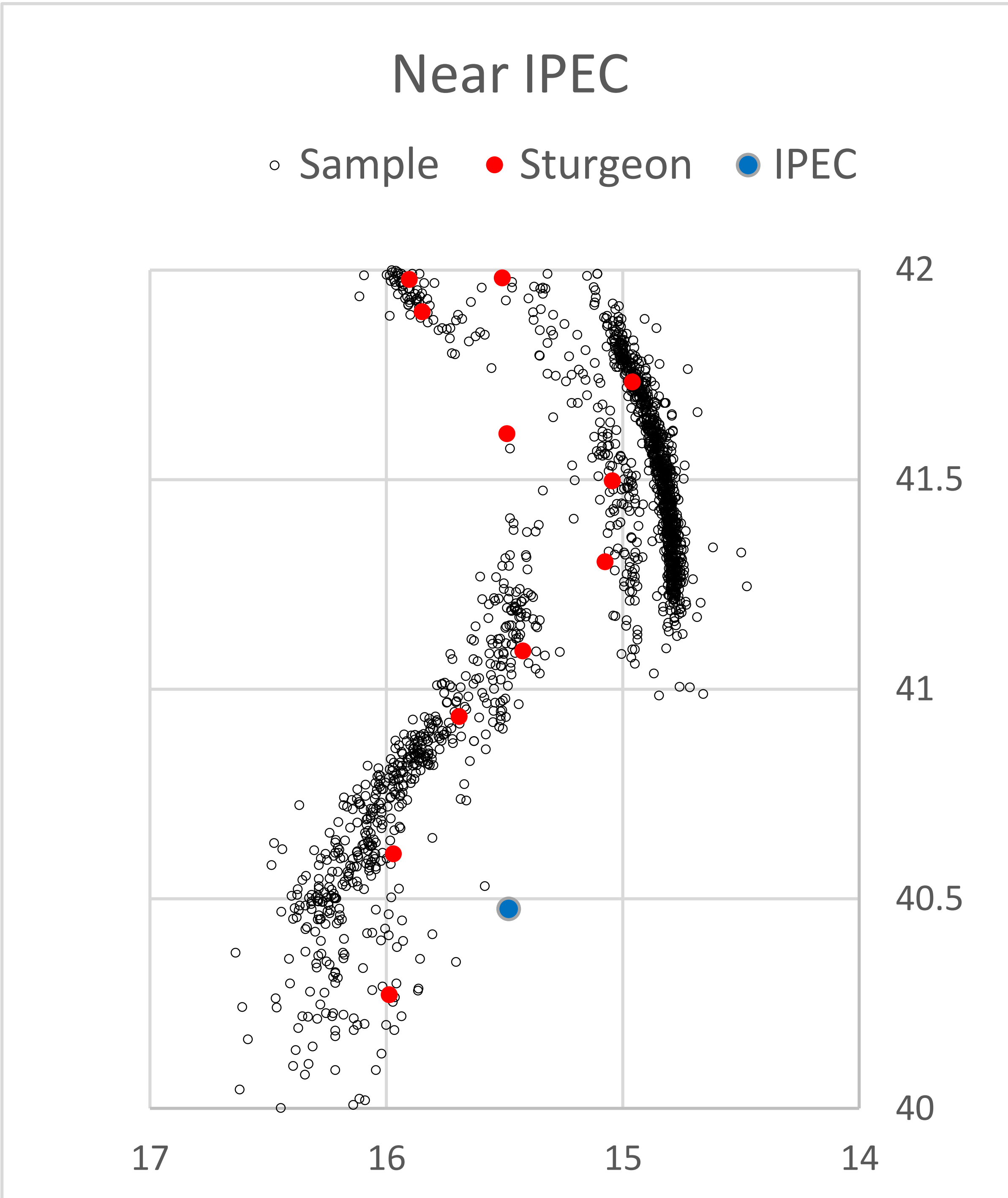
Plot of sampling locations within the Indian Point region and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled and beam trawl.



Plot of lower estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled and beam trawl.



Plot of upper estuary sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled and beam trawl.



Plot of near IPEC sampling locations and Atlantic sturgeon capture locations in LRS and FSS sampling from 2000-2014 using epibenthic sled and beam trawl.

ATTACHMENT B

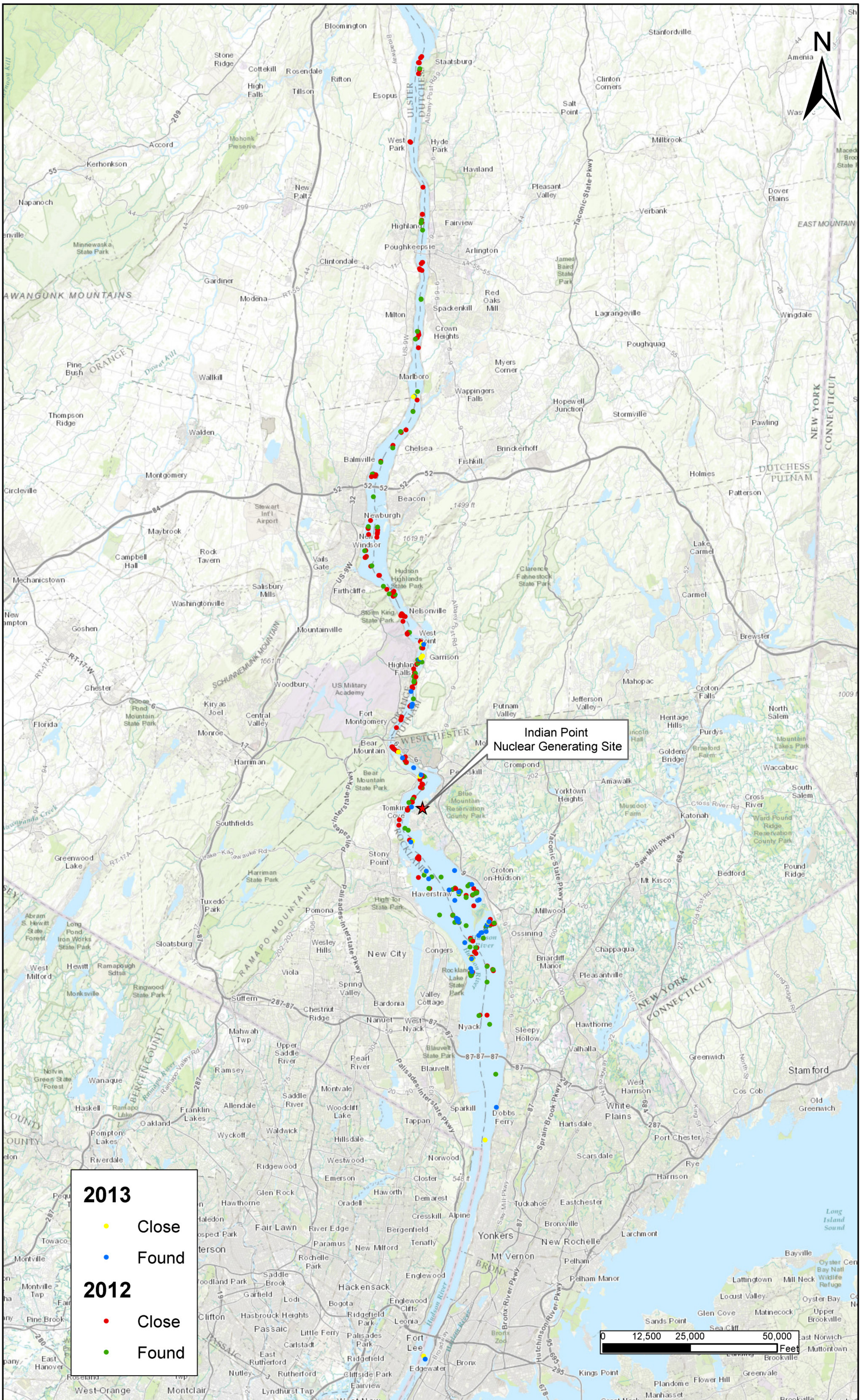


Figure B-1. NYSDEC tracking data showing acoustic tag detections for juvenile Atlantic sturgeon in the Hudson River tracked in 2012 and 2013. “Close” detections are assumed to give less precise positions than those designated as “Found,” as determined by the frequency detected by the receiver.

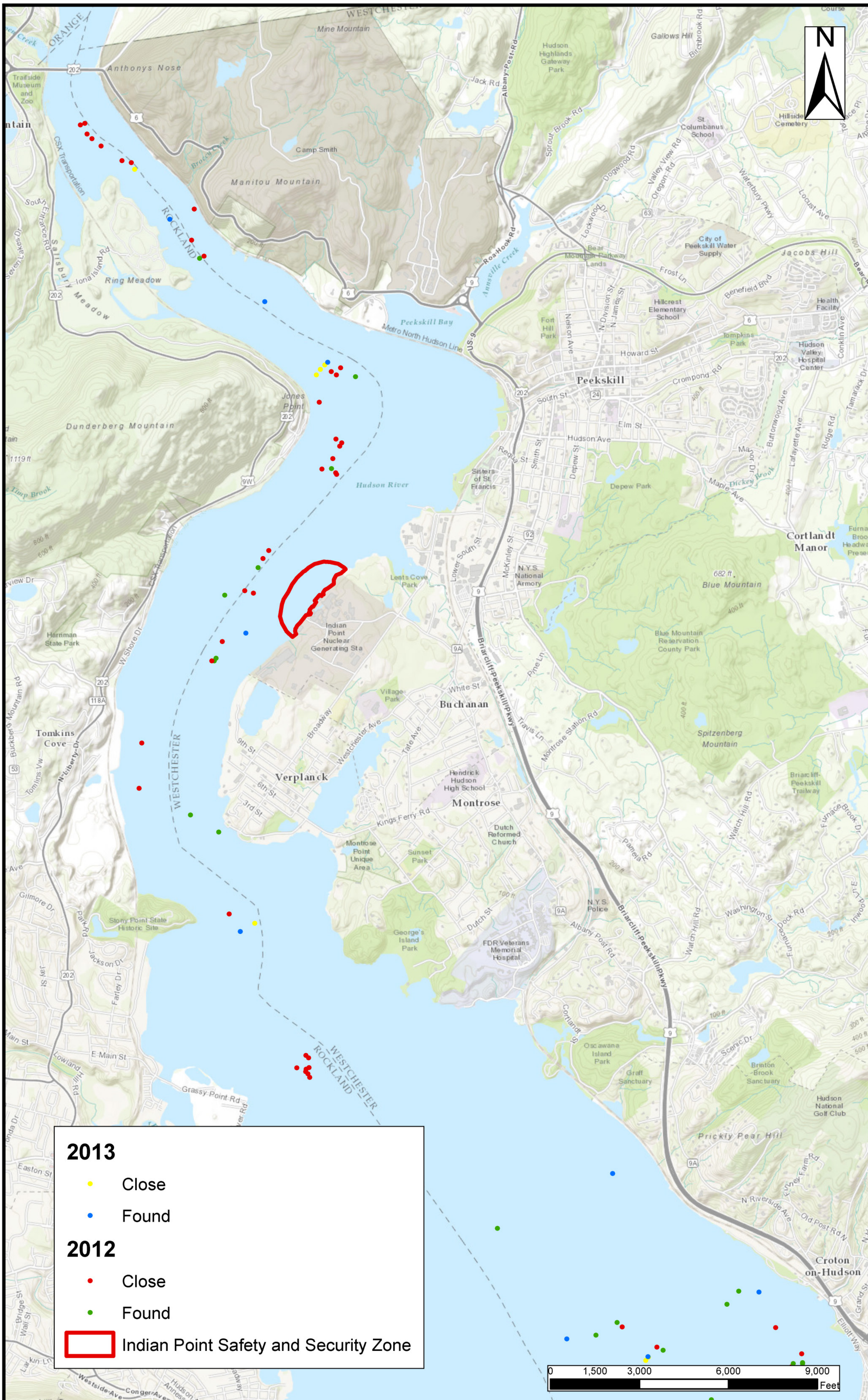
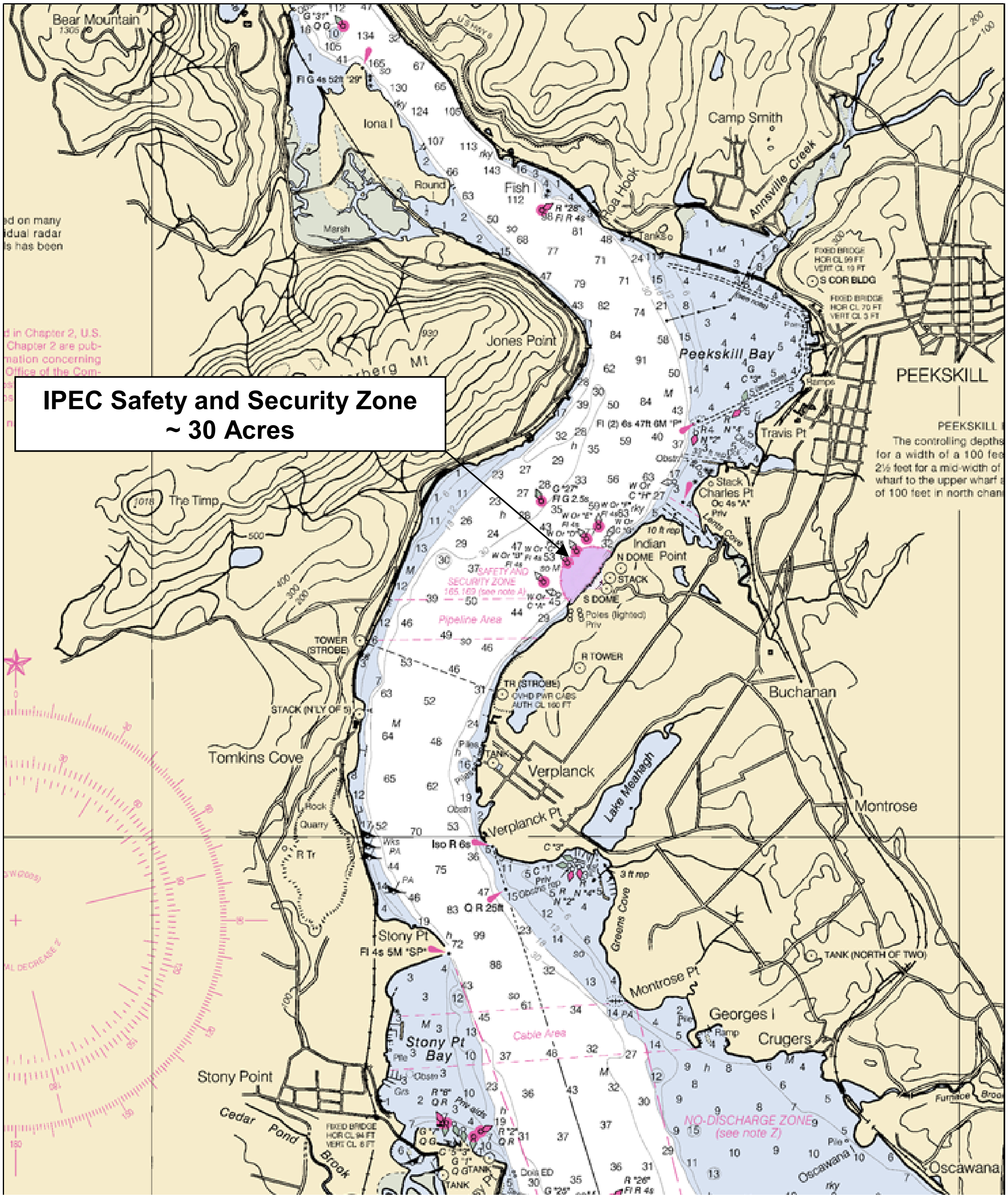


Figure B-2. NYSDEC tracking data showing acoustic tag detections for juvenile Atlantic sturgeon in the Indian Point region (river miles 39-46) of the Hudson River tracked in 2012 and 2013. “Close” detections are assumed to give less precise positions than those designated as “Found,” as determined by the frequency detected by the receiver.

ATTACHMENT C

SAFETY AND SECURITY ZONE RELATIVE TO IPEC REACH OF THE HUDSON RIVER (RIVER MILES 39-46)



30-Acre Safety and Security Zone is 0.7% of the 4,350 Acres in the IPEC Reach

ATTACHMENT D

8 August 2015

Technical Note on Analysis of Temperature and Dissolved Oxygen Trends from the Hudson River Biological Monitoring Program 1974 through 2013

This technical note investigates the presence of spatial and temporal trends in water temperature and dissolved oxygen ("DO") in the Hudson River as measured during the Fall Shoals (Juvenile) Survey ("FSS") and Long River Survey of ichthyoplankton ("LRS") of the Hudson River Biological Monitoring Program ("HRBMP"). Additional water quality data are available from surface water measurements taken nearshore during the Beach Seine Survey ("BSS"). Water quality data were examined from 1974 through 2013 to determine whether changes in sampling design affected results or interpretation of trend analysis in the updated PISCES report by Henderson and Seaby (2015, herein "PISCES report").

The PISCES report claimed that water temperature is increasing in the Hudson River based on the putative significant increasing temperature trend from 1951 through 2013 (see Figure 1 in PISCES report). The data source for this analysis originated from the 2013 Year Class Report (ASA 2015), Appendix B-6. The analysis was repeated using the same data and Figure 1 below corroborates the PISCES analysis.

However, as Figure 1 shows, the time series is highly variable and appears to consist of two clusters with the second cluster (higher temperatures) in the later period (Figure 1). Segmented regression analysis (SegReg software, January 2014 version, http://www. waterlog.info/segreg.htm) detected a significant break point separating the 1951-2013 temperature time series into two periods (1951-1978 and 1979-2013). Each period showed no trend within the period, but the two periods differed on average by 0.5°C (Figure 2).

The caption to Figure 1 in the PISCES report describes the time series as coming from a single sampling point at the Poughkeepsie Water Treatment Facility, which the authors purport to represent the thermal regime of the entire Hudson River system. While the timing may not align and may not explain this finding, it is important to clarify the footnote of Appendix B-6 in the 2013 Year Class Report clearly states only 1951 through 1992 data came from Poughkeepsie Water Treatment Facility and 1993 through 2013 data came from a US Geological Survey gaging site 01372058 in the Hudson River located five miles downstream from the Poughkeepsie Water Treatment Facility and from somewhat different depths, with the Poughkeepsie Water Works located 14 feet below low tide, and the present USGS gage located 10 feet above the river channel bottom. The PISCES report also does not explain why the more spatially robust data set consisting of over 200,000 temperature readings taken from the HRBMP over the majority of the year from the Battery to Albany (Table 1) was not used.

The water quality measurements from the HRBMP were used to investigate the presence of an increasing temperature trend and explain how temperature varied. This analysis examined the effect of subsetting the data a few different ways to determine the effect, if any, of documented temporal and spatial sampling design changes. For example, a significant increasing trend may be detected solely as a result of more measurements taken upriver and earlier in the year (cooler temperature) than in later years which would result in lower annual averages in early years and higher annual averages in later years. Not accounting for spatial and temporal sampling design inconsistencies could distort the time series and increase the probability of falsely detecting a significant trend as a result of sampling design.

Below are some highlighted steps in this analysis:

- The temporal distribution of valid observations (i.e., records with temperature, conductivity , and DO measurements) from the 1974-2013 time series of the Long River Survey, Fall Shoals Survey, and Beach Seine Survey (Task Codes included 88,89,98, and 23) were examined for consistency among years (Table 1), commonly sampled weeks and regions. The warmest month was selected by the four weeks with the highest temperature (Weeks 30-33; Table 2). In addition, Weeks 19-27 represented the longest contiguous period of years for LRS and FSS data (Table 3). The random biweekly beach seine sampling made the period for data selection more subjective but the effort in weeks 24 through 42 from 1987 through 2013 appeared most consistent (Table 4).
- The number of samples was examined for consistency in sampling effort among regions and years within the selected weeks. Since the Battery was not sampled until 1995, the data from the Battery was excluded so a longer time series can be retained.
- Six data sets were created based on sampling design considerations:
    - Data set #1 —All valid observations from FSS/LRS (Task Codes 88, 89, and 98) which varied in weeks sampled in the Yonkers through Albany regions (River Miles 12-152) over the years (1974-2013), plus samples from the ocean-influenced river mouth at the Battery region (River Miles 1-11) that was sampled for water quality measurements from 1995-2013. Water quality samples in this data set included measurements taken at random fisheries sampling stations from 1974 through 1981 and at fixed water quality stations from 1982 to present. This composite data set was analogous to the set of HRBMP water quality data analyzed in the PISCES report for DO, and it is unclear if the Pisces report analysis adjusted the data set prior to analysis for these temporal and spatial changes in sampling design over the 1974-2013 period.
    - Data set #2 —Subset of Data set #1 that includes data from a common contiguous period of weeks (week 19-27) and excludes the Battery which was not sampled before 1995 (Table 5).
    - Data set #3 —Data set #1 was further subset by retaining only those measurements taken at fixed sampling stations under Task Code = 89. Data set #3 represents the same weeks and regions for years 1982 through 2013 (Tables 6 and 7).
    - Data set #4 —These data consisted only of surface water measurements taken nearshore by the BSS. The BSS sampling schedule varied from weekly to every other week and would sometimes shift sampling weeks between years. For this analysis, sampling weeks 24-42 were selected from 1987 through 2013 (Tables 4 and 8).
    - Data set #5 —Data set #1 was further subset by retaining only those measurements taken at fixed sampling stations under Task Code = 89. Data set #5 represents the warmest weeks of 30-33 years 1988 through 2013 for all regions except the Battery (Tables 6 and 7).
    - Data set #6 —These data consisted only of surface water measurements taken nearshore by the BSS during the warmest month (weeks 30-33) from 1989 through 2013 (Tables 4 and 8).
- For each data set, the number of samples varied not only among regions within a year but also from year to year. To provide equal weighting among weeks, regions, and years, a stratified mean was used for the annual mean. All measurements were first averaged to produce a single value for each week and region within a year. Then, a weekly average was calculated by pooling the regions. The weekly means were averaged to produce a single annual mean value.

- Percent DO saturation, salinity and specific conductance at 25°C were calculated from temperature, DO concentration, and conductivity measurements based on established physical relationships (Benson and Krause 1984). It is particularly important to express DO as percent saturation because these three parameters are functionally correlated , and DO concentrations in water are inversely correlated with water temperature, meaning that warmer water will hold less DO due to its natural physical properties. Therefore, expressing DO concentrations as percent saturation holds this temperature relationship constant.

Results

- The year-to-year variability and magnitude of the time series differed depending on the sampling design selected and period selected (Figures 3 and 4).
- No statistically significant trend in water temperature over time was detected in all six time series (Figures 3 and 4).
- During years with high annual mean temperature (e.g., 1991, 1999, and 2010), temperature was elevated generally river wide. With elevated river water temperature occurring upriver to Albany, evidence that Indian Point discharge is responsible for biologically meaningful changes in the entire Hudson River ecosystem is lacking (Figure 5).
- Figure 5 also illustrates that weekly mean temperature increases from spring to summer. Any slight increasing trend in temperature, if present, would likely also be found in other east coast estuaries as a result of climate change. A long term data set for USGS or NOAA buoys could corroborate any regional warming trend if present.
- When sampling inconsistencies are resolved, a decreasing trend in DO concentration was detected in the standardized water quality sampling associated in LRS and FSS and random nearshore surface waters sampled by beach seine (Figure 6). A decreasing annual DO trend was also detected during the warmest months in nearshore waters sampled by the BSS (Figure 7).
- Figure 8 illustrates that DO decreases in the summer and decreases with region from upriver to downriver.
- Figures 9, 10, and 11 show temporal and spatial patterns in DO saturation that were similar to DO concentration.
- In general, the DO patterns observed herein corroborate trends detected in the PISCES report, but the PISCES report does not appear to link changes in IPECoperation with detected break point years and did not examine trends upriver that were also present. These observations are inconsistent with the hypothesis that IPEC is affecting DO trends in the Hudson River. In particular, the time series of Hudson River water temperatures measured at Poughkeepsie (River Miles 76 prior to 1993, River Mile 72 from 1993 to present) is from a sampling location considerable upstream from IPEC (River Mile 42) and not influenced by the station's thermal discharge. Other explanations such as recent major storms, particularly Hurricanes Irene (late August 2011) and Hurricane Sandy (late October 2012) increased run-off, sedimentation, destruction of aquatic vegetation beds, and other environmental factors were not explored or discounted by the PISCES report to establish a cause-effect relationship between IPEC operation and decreasing DO. These environmental factors may also have a greater effect in shallow nearshore waters.

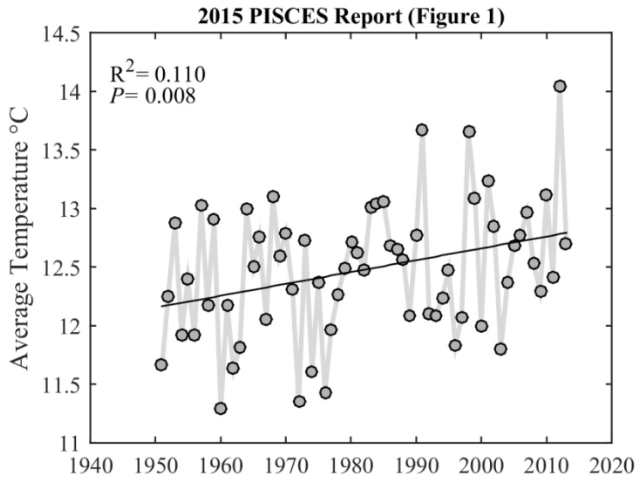


Figure 1. **Reproduced from the PISCES Report (Henderson and Seaby 2015) using digitized data from Appendix B-6 of the 2013 Year Class Report which corroborates their results in their Figure 1, but unlike their figure, the low R^2 reported here indicates that only 11% of the variation in annual temperature can be explained by time.**

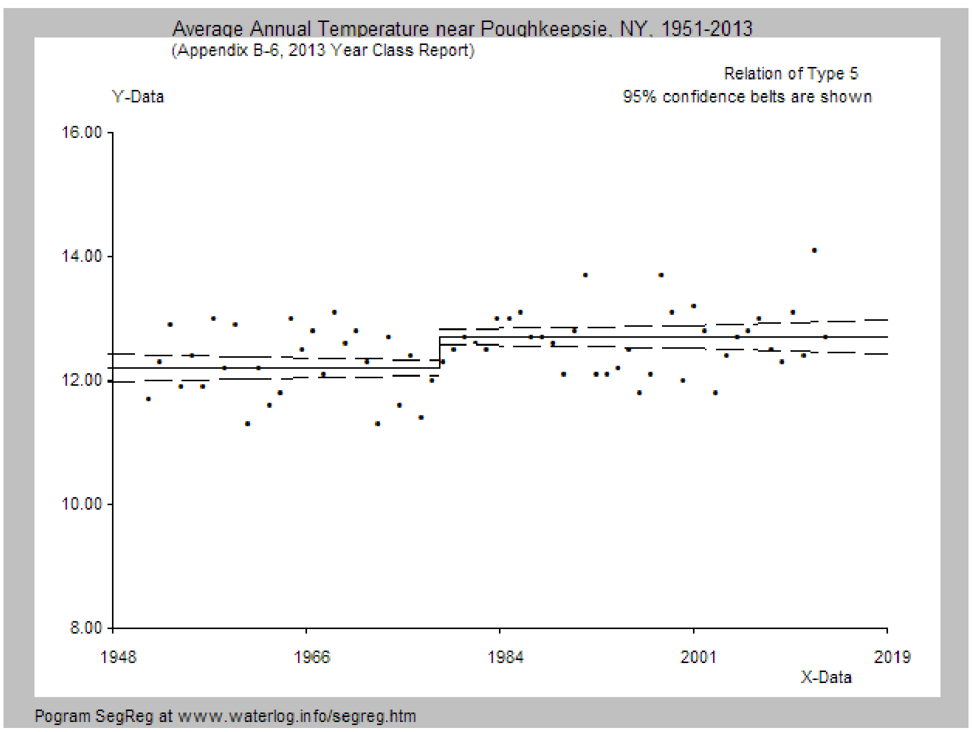


Figure 2. **1951 through 2013 annual mean water temperature from Appendix B-6 of the 2013 Year Class Report used in the PISCES Report (Henderson and Seaby 2015) consisted of a significant break point separating the time series into two periods (1951-1978 and 1979-2013) each with no trends (i.e., no significant slope) as detected by segmented regression analysis at 95% confidence level.**

Table 1. Distribution of water quality measurements among the Hudson River Beach Seine, Long River Ichthyoplankton and Fall Juvenile Surveys during 1974 through 2013.

Year	Sampling Design								Total	
	Beach Seine Stations (Task 23)		Ichthyoplankton (not standardized) (Task 88)		Fixed Water Quality Stations (Task 89)		Fall Juvenile (not standardized) (Task 98)			
	N	%	N	%	N	%	N	%	N	%
1974	556	0.3	2,481	1.1			1,652	0.8	4,689	2.1
1975	2,287	1.0	2,370	1.1					4,657	2.1
1976	3,442	1.6	3,487	1.6					6,929	3.1
1977	2,557	1.2	3,186	1.4			711	0.3	6,454	2.9
1978	3,550	1.6	2,822	1.3			746	0.3	7,118	3.2
1979	3,275	1.5	2,121	1.0			1,243	0.6	6,639	3.0
1980	1,411	0.6	1,016	0.5			1,006	0.5	3,433	1.6
1981	600	0.3	1,613	0.7			996	0.5	3,209	1.5
1982	498	0.2			1,382	0.6	719	0.3	2,599	1.2
1983	592	0.3			2,780	1.3			3,372	1.5
1984	799	0.4			2,943	1.3			3,742	1.7
1985	818	0.4			3,037	1.4			3,855	1.8
1986	937	0.4			3,415	1.6			4,352	2.0
1987	1,077	0.5			3,420	1.6			4,497	2.0
1988	1,082	0.5			3,855	1.8			4,937	2.2
1989	1,091	0.5			3,751	1.7			4,842	2.2
1990	989	0.4			3,489	1.6			4,478	2.0
1991	996	0.5			4,171	1.9			5,167	2.3
1992	994	0.5			4,202	1.9			5,196	2.4
1993	998	0.5			4,069	1.8			5,067	2.3
1994	995	0.5			4,163	1.9			5,158	2.3
1995	875	0.4			4,880	2.2			5,755	2.6
1996	991	0.5			4,898	2.2			5,889	2.7
1997	999	0.5			4,796	2.2			5,795	2.6
1998	997	0.5			5,490	2.5			6,487	2.9
1999	992	0.5			5,313	2.4			6,305	2.9
2000	994	0.5			5,493	2.5			6,487	2.9
2001	937	0.4			5,203	2.4			6,140	2.8
2002	993	0.5			5,436	2.5			6,429	2.9
2003	994	0.5			5,481	2.5			6,475	2.9
2004	996	0.5			5,521	2.5			6,517	3.0
2005	987	0.4			5,522	2.5			6,509	3.0
2006	967	0.4			5,506	2.5			6,473	2.9
2007	963	0.4			5,504	2.5			6,467	2.9
2008	993	0.5			5,517	2.5			6,510	3.0
2009	992	0.5			5,467	2.5			6,459	2.9
2010	992	0.5			5,518	2.5			6,510	3.0
2011	998	0.5			5,148	2.3			6,146	2.8
2012	996	0.5			4,752	2.2			5,748	2.6
2013	994	0.5			5,643	2.6			6,637	3.0
Total	48,194	21.9	19,096	8.7	145,765	66.2	7,073	3.2	220,128	100

Table 2. **Average weekly water temperature (°C) measured by Hudson River Fall Juvenile and Ichthyoplankton Surveys from 1974 through 2013. Bold values selected as warmest month (4 weeks).**

Week	Temperature (°C)
8	1.8
9	3.9
10	3.1
11	3.7
12	4.6
13	5.8
14	7.0
15	8.2
16	9.5
17	11.1
18	12.8
19	14.2
20	15.7
21	17.1
22	18.6
23	19.7
24	20.8
25	22.3
26	23.3
27	24.1
28	24.8
29	25.5
30	**25.6**
31	**25.8**
32	**25.9**
33	**25.6**
34	25.3
35	24.4
36	24.0
37	22.9
38	21.9
39	20.7
40	19.2
41	17.3
42	15.5
43	13.9
44	13.2
45	10.9
46	10.0
47	8.2
48	7.5
49	5.3
50	6.7

Table 3. Temporal distribution of dissolved oxygen measurements from any sampling stations during Hudson River Fall Juvenile and Ichthyoplankton Surveys during 1974-2013. Bold highlighted cells were selected to standardize for consistent sampled weeks among years.

Year	Week																																										
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1974								28	85	79	89	**147**	**156**	**168**	**140**	**175**	**188**	**163**	**157**	**150**	151	146	143	160	156	96	100	96	100	76	100	100	100	100	100	100	98	92	124	71	99	100	
1975			78		79		76		151		150	**151**	**148**	**144**	**153**	**115**	**156**	**152**	**120**	**131**	147	112	154		153																		
1976	19	94	90		98		91		204	207	197	**205**	**203**	**212**	**202**	**200**	**211**	**211**	**210**	**206**	210		211		206																		
1977	92		93		89		89		176	196	193	**196**	**192**	**176**	**177**	**191**	**188**	**190**	**188**	**190**	199		195		176	88		99		98		97		91		82		81	4	49		22	
1978						96		85	181	183	191	**185**	**189**	**190**	**182**	**176**	**182**	**184**	**198**	**114**		174		173		139	95		90		78		89		91		65		74		89		75
1979					79		56		97	135	182	**165**	**148**	**162**	**144**	**155**	**88**	**122**	**164**	**112**	22	89	76	88	170	135	89		150		40		142		156		92		98		134		74
1980				8	28	31	20	37		40	90	**98**	**89**	**101**	**102**	**110**	**79**	**91**	**92**	**92**		97		88		86		73		73		24		84		183		93		61		52	
1981											135	**106**	**199**	**196**	**195**	**164**	**66**	**189**	**168**	**195**					148		166		175		185		184		138								
1982												**124**	**165**	**200**	**146**	**134**	**167**	**113**	**166**	**167**					44	27	156	15	149		164		164										
1983											177	**176**	**177**	**177**	**177**	**177**	**177**	**183**	**192**	**142**					169		167		175		175		167		172								
1984												**165**	**161**	**161**	**164**	**164**	**165**	**164**	**164**	**161**	164	164		166		166		156		164		166		164		164							
1985										131	164	**164**	**164**	**132**	**154**	**164**	**142**	**135**	**166**	**159**		118		127	40	164		142		133		151		166		164	16	141					
1986										164	164	**164**	**164**	**163**	**165**	**156**	**161**	**165**	**165**	**164**		164		165		142		163		165		165		160		165		166	48	85	32		
1987								68	129	158	188	**135**	**123**	**165**	**163**	**156**	**165**	**161**	**164**	**164**	164		164		163		164		164		164		164		167		167						
1988									163	167	167	**167**	**167**	**167**	**167**	**167**	**167**	**167**	**167**	**167**	104	166	104	167	104	167	104	167	104	167		167	19	148	11	156							
1989									167	166	167	**167**	**167**	**167**	**167**	**167**	**167**	**167**	**165**	**167**	104	167	104	167	104	167	104	167		167		165		167	21	146							
1990									114	189	167	**167**	**167**	**167**	**167**	**168**	**167**	**167**	**167**	**170**	167	104	167	104	140	104	156		136		141		158		135								
1991								167	167	167	170	**167**	**167**	**167**	**164**	**164**	**170**	**178**	**161**	**167**	167	104	167	104	152	104	167	94	164	107	167	104	167	60	167								
1992								146	167	167	167	**168**	**167**	**167**	**167**	**167**	**167**	**167**	**161**	**173**	167	104	167	104	167	104	167	104	167	102	156	104	167	104	167								
1993									167	167	169	**167**	**165**	**167**	**167**	**167**	**167**	**167**	**167**	**167**	105	167	104	167	104	167	104	167	104	167	104	167	104	167		167							
1994								166	167	152	140	**168**	**165**	**170**	**167**	**160**	**167**	**170**	**161**	**163**	94	167	99	162	104	167	106	167	104	167	104	167	108	164		167							
1995			107		107		107	182	182	200	164	**182**	**206**	**158**	**182**	**182**	**182**	**182**	**203**	**161**	170	119	170	121	170	117	170	141	149	119	169	119	170	119	170								
1996			44	107		107	31	182	182	182	182	**183**	**182**	**182**	**182**	**180**	**182**	**182**	**212**	**154**	162	141	182	119	140	119	182	119	182	120	182	119	182	130	163								
1997			107		107		182	182	182	182	182	**182**	**182**	**109**	**182**	**182**	**182**	**203**	**161**	**184**	119	182	119	182	119	182	119	182	118	182	119	181	119	182									
1998		107		77		107	182	182	179	182	182	**182**	**182**	**182**	**182**	**182**	**179**	**185**	**182**	**182**	120	182	119	182	119	182	119	182	119	182	119	182	119	182		182		182			182		
1999					63	107	179	182	188	178	182	**182**	**180**	**182**	**182**	**182**	**182**	**185**	**182**	**188**	119	179	119	182	119	182	119	182	119	182	119	181	119	182		122		182			182		
2000			107		107	107	182	180	182	182	182	**182**	**182**	**182**	**184**	**180**	**182**	**182**	**179**	**170**	119	182	119	182	116	185	119	176	116	179	119	182	119	182		182		179		3	182		
2001				79		107	107	164	161	182	185	**182**	**182**	**182**	**180**	**179**	**182**	**179**	**200**	**155**	182	119	180	119	185	119	182	119	182		164	107	172	107	173		176		136		175		
2002		107		107		107	185	179	182	182	182	**182**	**182**	**182**	**182**	**182**	**179**	**191**	**167**	**182**	119	182	119	182	119	182	119	176	53	185	119	182	117	182		182		182			176		
2003				99	107	107	161	179	182	181	182	**182**	**180**	**182**	**182**	**182**	**182**	**200**	**164**	**185**	119	179	119	182	119	182	119	182	116	179	119	182	119	182		182			182		182		
2004		107		107		107	182	185	182	182	182	**182**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	119	182	119	182	119	182	119	181	119	179	119	182	119	182		182		182			182		
2005				107	107	107	182	182	182	182	182	**182**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	119	182	119	182	119	182	119	184	119	180	119	182	119	182		182		182			182		
2006			107		107	107	182	182	182	182	182	**182**	**182**	**182**	**182**	**182**	**178**	**179**	**182**	**182**	119	182	119	173	119	182	119	182	119	182	119	182	119	182		182		182			182		
2007				102	102	107	180	182	179	182	182	**182**	**182**	**182**	**182**	**182**	**186**	**182**	**221**	**140**	119	182	119	182	119	182	119	182	119	182	119	182	119	182		182		182		5	174		
2008		107		107		107	181	182	182	182	182	**182**	**182**	**182**	**182**	**182**	**182**	**188**	**176**	**182**	119	182	119	182	119	182	119	182	119	182	119	182	118	182		182		182			179		
2009				107	106	107	182	182	182	182	182	**182**	**182**	**182**	**182**	**182**	**131**	**182**	**182**	**182**	119	182	119	182	116	182	119	182	119	182	119	182	119	182		182		182			182		
2010				107	107	104	182	185	182	182	182	**182**	**182**	**179**	**182**	**182**	**182**	**182**	**182**	**182**	119	179	122	182	119	182	119	182	118	182	119	182	119	182		182		182			182		
2011				63	107	94	115	124	110	182	185	**179**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	**182**	119	182	119	182	119	182	62	119	119	182	119	182	119	182		182		182			182		
2012		107		107		75					177	**183**	**176**	**182**	**182**	**182**	**182**	**182**	**176**	**182**	119	182	119	182	119	182	119	182	119	182	119	182	119	188		182		182			182		
2013			107	107	107	185	182	182	182	182	182	**182**	**182**	**182**	**182**	**182**	**186**	**213**	**154**	**119**	215	119	185	119	195	119	236	119	188	119	182	119	182		182		185		182				

Table 4. **Temporal distribution of dissolved oxygen measurements from any sampling stations during Hudson River Beach Seine Surveys during 1974-2013. Gray highlighted cells were selected to standardize for longest period of similar sampling effort among weeks and years. Bold values represent the weeks selected for the warmest month.**

Year	Week																																					
	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1974										30	30	37	1	11	33	33	45	35	36	39	35	37	31	46	19	30	28												
1975	15	61	62	67	53	72	59	65	54	66	47	79	67	45	73	69	66	**60**	**68**	**63**	**77**	67	63	77	56	68	63	75	62	69	52	67	62	68	34	30	70	16	
1976	50	103	83	92	106	99	101	109	90	91	92	96	106	108	101	101	100	**101**	**103**	**99**	**104**	105	99	93	99	98	89	100	99	104	85	78	100	99	102	29	28		
1977		101	81	97	99	101	81	106	97	89	100	100	84	104	105	110	99	**94**	**101**	**102**	**85**	100	101	92	119	100	101	8											
1978		96	95	104	101	92	93	98	98	89	100	102	108	99	98	98	89	**99**	**100**	**76**	**97**	101	101	102	92	95	100	98	94	81	88	100	94	100	100	102	72	90	8
1979		99	100	89	75	97	95	78	63	93	90	100	97	83	89	86	72	**93**	**77**	**98**	**78**	98	94	90	98	90	86	96	81	99	69	91	83	97	71	80	100	100	
1980														56	93	97	99	**96**	**99**	**102**	**99**	97		95		83		92		98		51		98		56			
1981																			**89**		**91**		52		99		99		79		91								
1982																					**98**		100		100		100		100										
1983																			**98**		**100**		99		93		100		102										
1984																		**98**		**102**		99		100		100		100		100		100							
1985																86		**51**		**99**		97		78		53		98		98		58		100					
1986																96		**98**		**99**		76		97		98		99		83		93		98					
1987													99		85		100		**99**		**99**		98		99		98		101		100		99						
1988												99		99		99		**100**		**100**		88		100		99		100		98		100							
1989												98		100		100		**99**		**100**		99		99		98		99		99		100							
1990													100		89		100		**100**		**100**		100		100		100		100		100								
1991													100		100		100		**99**		**100**		98		100		100		100		99								
1992													100		100		99		**100**		**100**		95		100		100		100		100								
1993														99		100		**100**		**100**		100		100		100		100		100		99							
1994														99		99		**100**		**100**		99		100		100		98		100		100							
1995													82		91		96		**60**		**88**		84		82		97		95		100								
1996													100		97		100		**100**		**98**		98		100		99		99		100								
1997												100		100		100		**100**		**100**		100		100		100		99		100									
1998												100		100		100		**98**		**100**		99		100		100		100		100									
1999												100		100		100		**100**		**100**		100		100		100		98		94									
2000												99		98		100		**100**		**100**		100		98		100		100		99									
2001													98	24	71		97		**99**		**100**		98		51		100		100		99								
2002												100		99		98		**100**		**100**		100		99		98		99		100									
2003												100		99		100		**99**		**100**		99		99		99		99		100									
2004												99		100		100		**98**		**100**		100		100		100		99		100									
2005												97		98		100		**99**		**99**		100		98		96		100		100									
2006												100		100		99		**99**		**98**		99		100		74		98		100									
2007												75		99		99		**98**		**97**		98		100		97		100		100									
2008												100		99		100		**99**		**98**		100		98		100		99		100									
2009												99		100		98		**100**		**100**		100		97		100		98		100									
2010												100		96		100		**100**		**97**		99		100		100		100		100									
2011												100		99		100		**100**		**100**		100		100		99		100		100									
2012												100		99		100		**99**		**98**		100		100		100		100		100									
2013											99		99		100		99		**99**		**99**		100		100		99		100										

Table 5. Regional distribution of dissolved oxygen measurements from any sampling stations during Hudson River Fall Juvenile and Long River Ichthyoplankton Surveys during consistently sampled Weeks 19-27 of 1974 through 2013.

Year	Region												
	BT	YK	TZ	CH	IP	WP	CW	PK	HP	KG	SG	CS	AL
1974		142	270	144	149	104	106	161	104	96	90	53	25
1975		75	154	135	203	123	39	236	82	85	64	42	32
1976		83	197	229	344	249	226	175	115	89	70	58	25
1977		63	112	142	263	262	211	238	116	98	76	75	32
1978		62	112	129	294	276	150	199	111	98	67	66	36
1979		49	70	93	160	162	84	123	119	123	113	128	36
1980		12	47	51	136	185	72	74	75	58	53	49	42
1981		104	135	132	276	299	173	107	90	56	47	40	19
1982		131	122	118	141	108	144	135	114	93	84	96	96
1983		162	162	159	156	108	159	135	108	108	105	108	108
1984		142	144	145	143	108	142	108	108	108	105	108	108
1985		141	125	121	108	108	138	108	108	108	108	108	99
1986		144	143	149	141	99	144	108	108	107	108	108	108
1987		126	133	147	144	102	138	93	96	99	105	105	108
1988		144	144	144	144	108	144	108	108	108	108	108	135
1989		144	141	145	141	108	147	108	108	108	108	108	135
1990		144	144	118	171	108	147	108	108	108	108	108	135
1991		144	144	144	146	108	144	108	108	108	108	108	135
1992		144	144	145	144	108	144	108	108	108	108	108	135
1993		144	142	144	144	108	144	108	108	108	108	108	135
1994		131	143	143	144	111	144	108	108	108	108	108	135
1995	108	171	144	144	144	108	144	108	108	108	108	108	135
1996	108	172	144	143	146	108	143	108	108	108	108	108	135
1997	108	174	146	145	144	105	143	96	95	99	96	96	120
1998	108	171	147	144	141	108	144	108	108	108	108	108	135
1999	108	169	144	144	147	114	141	108	108	108	108	111	135
2000	96	171	144	144	144	108	144	108	108	108	108	108	132
2001	99	171	144	142	141	108	144	108	108	105	108	108	135
2002	102	171	144	144	144	108	144	108	108	108	108	105	135
2003	108	171	144	144	142	108	144	108	108	111	108	108	135
2004	108	171	144	144	144	108	144	108	108	108	108	108	135
2005	108	171	144	144	150	105	144	108	105	108	108	108	135
2006	105	171	143	144	144	105	144	108	108	108	108	108	135
2007	108	171	144	144	144	108	144	108	108	108	108	108	135
2008	108	171	144	144	144	108	144	108	108	108	108	108	135
2009	108	171	144	144	144	108	144	108	108	96	96	96	120
2010	108	171	141	144	144	108	144	108	108	108	108	108	135
2011	108	168	144	144	144	108	144	108	108	108	108	108	135
2012	108	168	142	144	144	108	144	105	108	108	108	105	135
2013	108	171	144	147	144	111	144	108	96	96	96	96	120

Table 6. Temporal distribution of dissolved oxygen measurements from standardized fixed sampling stations (Task Code =89) during Hudson River Fall Juvenile and Long River Ichthyoplankton Surveys during 1982-2013. Gray highlighted cells were selected to standardize for longest period of similar sampling effort among weeks and years. Bold values represent the weeks selected for the warmest month.

Year	Week																																							
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
1982											124	165	200	146	134	167	113	166	167																					
1983										177	176	177	177	177	177	177	183	192	142					169		167		175		175		167		172						
1984											165	161	161	164	164	165	164	164	161	164	164		166		166		156		164		166		164		164					
1985									131	164	164	164	152	154	164	142	135	166	159		118		127	40	164		142		133		151		166		164	16	141			
1986									164	164	164	164	163	165	156	161	165	165	164		164		165		142		163		165		165		160		163		166	48	85	32
1987							65	129	158	188	135	123	165	163	156	165	161	164	164	164		164		163		164		164		164		164		167		167				
1988								163	167	167	167	167	167	167	167	167	167	167	167	104	166	**104**	**167**	**104**	**167**	104	167	104	167		167	19	148	11	156					
1989								167	166	167	167	167	167	167	167	167	167	165	167	104	167	**104**	**167**	**104**	**167**	104	167		167		165		167	21	146					
1990								114	189	167	167	167	167	167	168	167	167	167	170	167	104	**167**	**104**	**140**	**104**	156		136		141		158		135						
1991							167	167	167	170	167	167	167	164	164	170	178	161	167	167	104	**167**	**104**	**152**	**104**	167	94	164	107	167	104	167	60	167						
1992							146	167	167	167	168	167	167	167	167	167	167	161	173	167	104	**167**	**104**	**167**	**104**	167	104	167	102	156	104	167	104	167						
1993								167	167	169	167	165	167	167	167	167	167	167	167	105	167	**104**	**167**	**104**	**167**	104	167	104	167	104	167	104	167		167					
1994							166	167	152	140	168	165	170	167	160	167	170	161	163	94	167	**99**	**162**	**104**	**167**	106	167	104	167	104	167	108	164		167					
1995		107		107		107	182	182	200	164	182	206	158	182	182	182	182	203	161	170	119	**170**	**121**	**170**	**117**	170	141	149	119	169	119	170	119	170						
1996		44	107		107	31	182	182	182	182	183	182	182	182	180	182	182	212	154	162	141	**182**	**119**	**140**	**119**	182	119	182	120	182	119	182	130	163						
1997		107		107		182	182	182	182	182	182	182	109	182	182	182	203	161	184	119	182	**119**	**182**	**119**	**182**	119	182	118	182	119	181	119	182							
1998	107		77		107	182	182	179	182	182	182	182	182	182	182	179	185	182	182	120	182	**119**	**182**	**119**	**182**	119	182	119	182	119	182	119	182		182		182			182
1999				63	107	179	182	188	178	182	182	180	182	182	182	182	185	182	188	119	179	**119**	**182**	**119**	**182**	119	182	119	182	119	181	119	182		122		182			182
2000		107		107	107	182	180	182	182	182	182	182	182	184	180	182	182	179	170	119	182	**119**	**182**	**116**	**185**	119	176	116	179	119	182	119	182		182		179		3	182
2001			79		107	107	164	161	182	185	182	182	182	180	179	182	179	200	155	182	119	**180**	**119**	**185**	**119**	182	119	182		164	107	172	107	173		176		136		175
2002	107		107		107	185	179	182	182	182	182	182	182	182	182	179	191	167	182	119	182	**119**	**182**	**119**	**182**	119	176	53	185	119	182	117	182		182		182			176
2003			99	107	107	161	179	182	181	182	182	180	182	182	182	182	200	164	185	119	179	**119**	**182**	**119**	**182**	119	182	116	179	119	182	119	182		182			182		182
2004	107		107		107	182	185	182	182	182	182	182	182	182	182	182	182	182	182	119	182	**119**	**182**	**119**	**182**	119	181	119	179	119	182	119	182		182		182			182
2005			107	107	107	182	182	182	182	182	182	182	182	182	182	182	182	182	182	119	182	**119**	**182**	**119**	**182**	119	184	119	180	119	182	119	182		182		182			182
2006		107		107	107	182	182	182	182	182	182	182	182	182	182	178	179	182	182	119	182	**119**	**173**	**119**	**182**	119	182	119	182	119	182	119	182		182		182			182
2007			102	102	107	180	182	179	182	182	182	182	182	182	182	185	182	221	140	119	182	**119**	**182**	**119**	**182**	119	182	119	182	119	182	119	182		182		182		5	174
2008	107		107		107	181	182	182	182	182	182	182	182	182	182	182	188	176	182	119	182	**119**	**182**	**119**	**182**	119	182	119	182	119	182	118	182		182		182			179
2009			107	106	107	182	182	182	182	182	182	182	182	182	182	131	182	182	182	119	182	**119**	**182**	**116**	**182**	119	182	119	182	119	182	119	182		182		182			182
2010			107	107	104	182	185	182	182	182	182	182	179	182	182	182	182	182	182	119	179	**122**	**182**	**119**	**182**	119	182	118	182	119	182	119	182		182		182			182
2011			63	107	94	115	124	110	182	185	179	182	182	182	182	182	182	182	182	119	182	**119**	**182**	**119**	**182**	62	119	119	182	119	182	119	182		182		182			182
2012	107		107		75					177	183	176	182	182	182	182	182	176	182	119	182	**119**	**182**	**119**	**182**	119	182	119	182	119	182	119	188		182		182			182
2013		107	107	107	185	182	182	182	182	182	182	182	182	182	182	185	213	154	119	215	119	**185**	**119**	**195**	**119**	236	119	188	119	182	119	182		182		185		182		

Table 7. Regional distribution of dissolved oxygen measurements from fixed sampling stations during Hudson River Fall Juvenile and Long River Ichthyoplankton Surveys during consistently sampled Weeks 19-27 of 1982 through 2013.

Year	Region												
	BT	YK	TZ	CH	IP	WP	CW	PK	HP	KG	SG	CS	AL
1982		131	122	118	141	108	144	135	114	93	84	96	96
1983		162	162	159	156	108	159	135	108	108	105	108	108
1984		142	144	145	143	108	142	108	108	108	105	108	108
1985		141	125	121	108	108	138	108	108	108	108	108	99
1986		144	143	149	141	99	144	108	108	107	108	108	108
1987		126	133	147	144	102	138	93	96	99	105	105	108
1988		144	144	144	144	108	144	108	108	108	108	108	135
1989		144	141	145	141	108	147	108	108	108	108	108	135
1990		144	144	118	171	108	147	108	108	108	108	108	135
1991		144	144	144	146	108	144	108	108	108	108	108	135
1992		144	144	145	144	108	144	108	108	108	108	108	135
1993		144	142	144	144	108	144	108	108	108	108	108	135
1994		131	143	143	144	111	144	108	108	108	108	108	135
1995	108	171	144	144	144	108	144	108	108	108	108	108	135
1996	108	172	144	143	146	108	143	108	108	108	108	108	135
1997	108	174	146	145	144	105	143	96	95	99	96	96	120
1998	108	171	147	144	141	108	144	108	108	108	108	108	135
1999	108	169	144	144	147	114	141	108	108	108	108	111	135
2000	96	171	144	144	144	108	144	108	108	108	108	108	132
2001	99	171	144	142	141	108	144	108	108	105	108	108	135
2002	102	171	144	144	144	108	144	108	108	108	108	105	135
2003	108	171	144	144	142	108	144	108	108	111	108	108	135
2004	108	171	144	144	144	108	144	108	108	108	108	108	135
2005	108	171	144	144	150	105	144	108	105	108	108	108	135
2006	105	171	143	144	144	105	144	108	108	108	108	108	135
2007	108	171	144	144	144	108	144	108	108	108	108	108	135
2008	108	171	144	144	144	108	144	108	108	108	108	108	135
2009	108	171	144	144	144	108	144	108	108	96	96	96	120
2010	108	171	141	144	144	108	144	108	108	108	108	108	135
2011	108	168	144	144	144	108	144	108	108	108	108	108	135
2012	108	168	142	144	144	108	144	105	108	108	108	105	135
2013	108	171	144	147	144	111	144	108	96	96	96	96	120

Table 8. Regional distribution of dissolved oxygen measurements from during Hudson River Beach Seine Surveys during consistently sampled Weeks 24-42 of 1974 through 2013.

Year	Region											
	YK	TZ	CH	IP	WP	CW	PK	HP	KG	SG	CS	AL
1974		1	1	9	4	2	88	52	31	69	100	139
1975	146	147	174	128	178	132	57	41	33	56	74	101
1976	216	199	234	394	202	190	81	44	30	61	104	150
1977	215	143	166	335	190	170	62	34	31	43	84	132
1978	214	256	313	243	168	164	151	28	25	51	79	138
1979	100	489	286	103	91	122	103	52	54	101	112	92
1980	60	293	169	65	62	78	56	61	64	107	107	84
1981	30	136	61	22	29	34	29	28	25	39	47	29
1982	25	119	70	25	25	30	25	25	25	44	50	35
1983	30	134	84	32	30	37	30	29	31	54	59	42
1984	35	167	98	37	34	41	35	35	35	63	70	49
1985	35	169	88	37	30	34	20	20	26	64	81	56
1986	35	166	99	39	40	46	39	40	36	71	78	57
1987	43	216	124	42	40	48	42	45	44	82	89	63
1988	44	201	118	44	44	51	53	54	58	107	125	83
1989	42	200	117	44	44	51	57	59	59	107	126	85
1990	39	176	106	39	39	45	54	54	50	92	116	79
1991	39	177	104	39	38	45	54	54	53	99	117	78
1992	39	177	105	39	37	45	53	54	53	99	115	78
1993	39	176	105	39	39	45	54	54	54	99	117	78
1994	39	175	104	39	38	45	54	54	54	99	116	78
1995	38	140	82	33	39	40	45	47	46	85	107	73
1996	38	175	103	39	39	44	53	54	54	98	116	78
1997	44	200	119	44	44	51	59	59	59	108	127	85
1998	44	201	119	44	44	51	59	59	59	106	126	85
1999	44	201	112	44	44	50	59	59	59	108	127	85
2000	44	200	119	44	44	51	57	59	58	108	125	85
2001	34	152	91	33	37	44	53	54	52	97	113	78
2002	44	200	119	44	44	51	57	59	57	106	127	85
2003	44	198	119	44	42	51	59	59	59	108	126	85
2004	44	200	119	44	43	50	59	59	58	109	126	85
2005	44	197	117	44	42	51	59	59	59	106	125	84
2006	42	198	116	38	38	45	54	58	59	107	127	85
2007	43	195	117	44	41	48	49	54	57	105	125	85
2008	44	199	116	44	44	51	58	59	59	107	127	85
2009	44	199	117	43	44	51	59	58	58	108	126	85
2010	44	201	119	42	43	51	58	58	58	107	126	85
2011	44	200	119	44	44	51	59	59	59	107	127	85
2012	44	201	117	44	44	51	59	58	59	108	126	85
2013	41	187	111	41	41	48	50	51	51	93	108	73

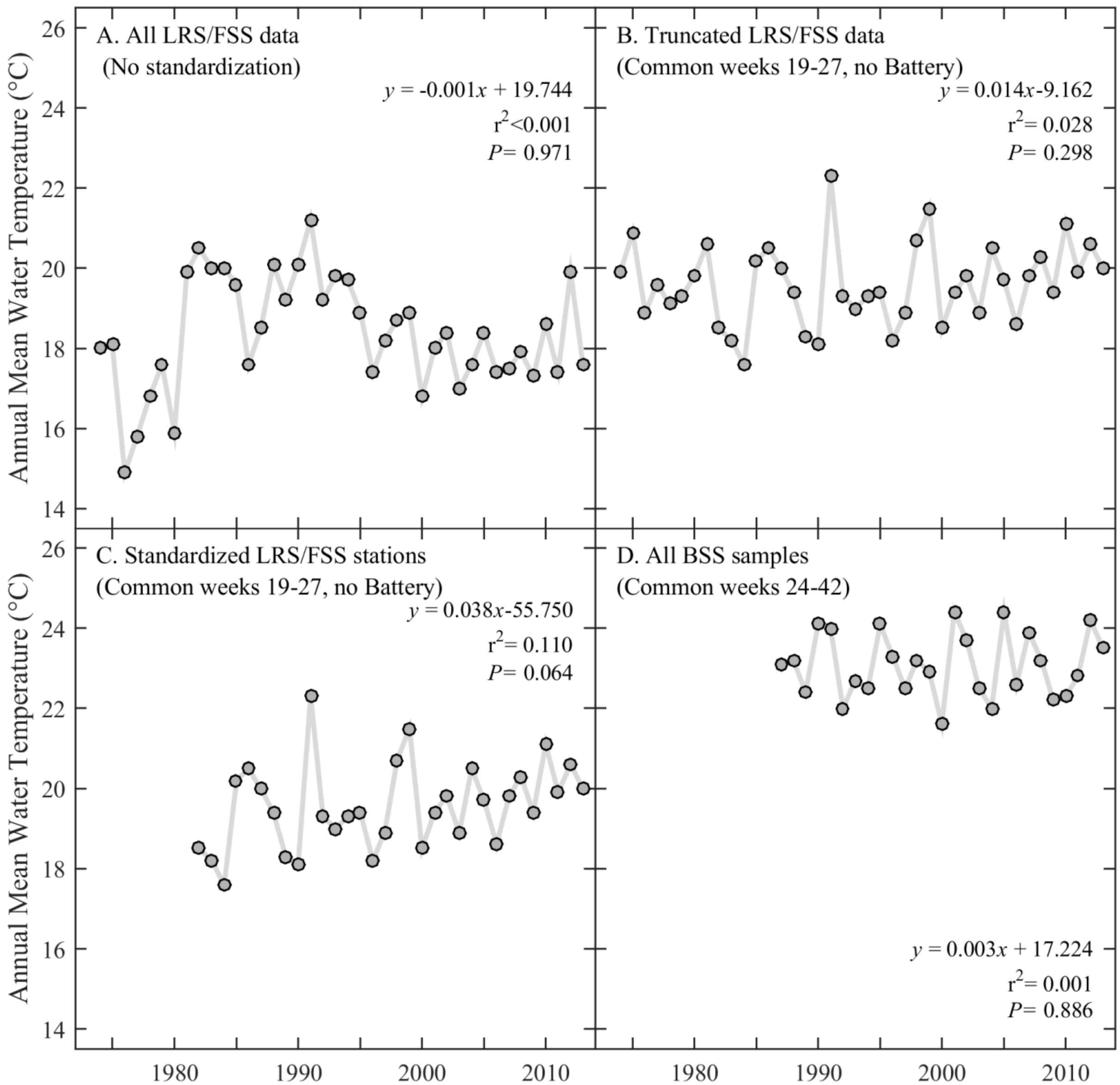


Figure 3. **Annual Mean Water Temperature in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except truncated for consistency in sampled weeks and regions over time; C) LRS/FSS data (Task Code=89 only) collected at the fixed sampling water quality stations standardized for common weeks and regions among years; D) All Beach Seine Survey data during weeks 23-42 representing a common period among the majority of years. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the weekly averages. *P* = probability value less than 0.05 considered significant at the 95% confidence level.**

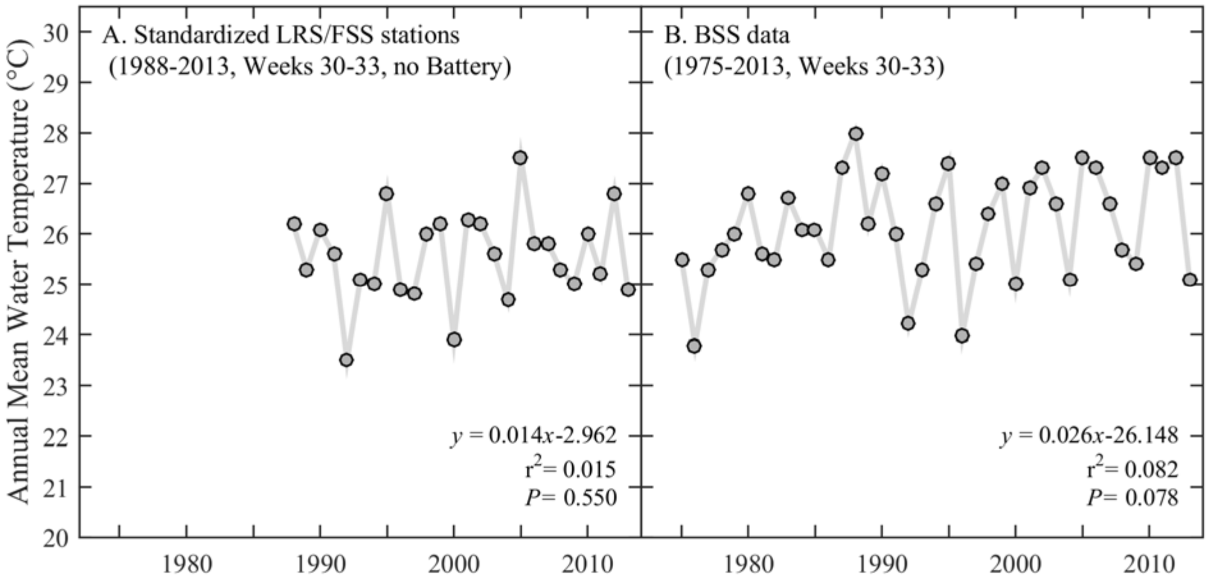


Figure 4. **Annual Mean Water Temperature for the Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among all regions from Yonkers to Albany. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the weekly averages. *P* = probability value less than 0.05 considered significant at the 95% confidence level.**

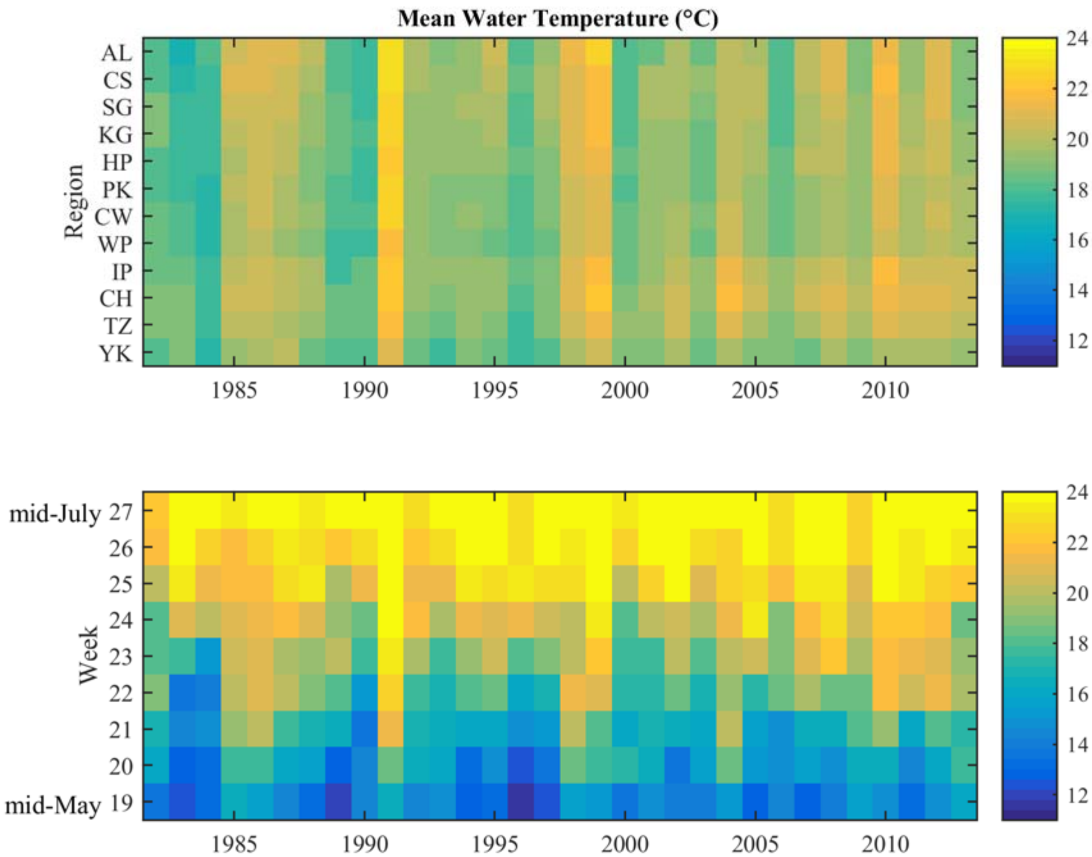


Figure 5. Image plots illustrating the variation in water temperature by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

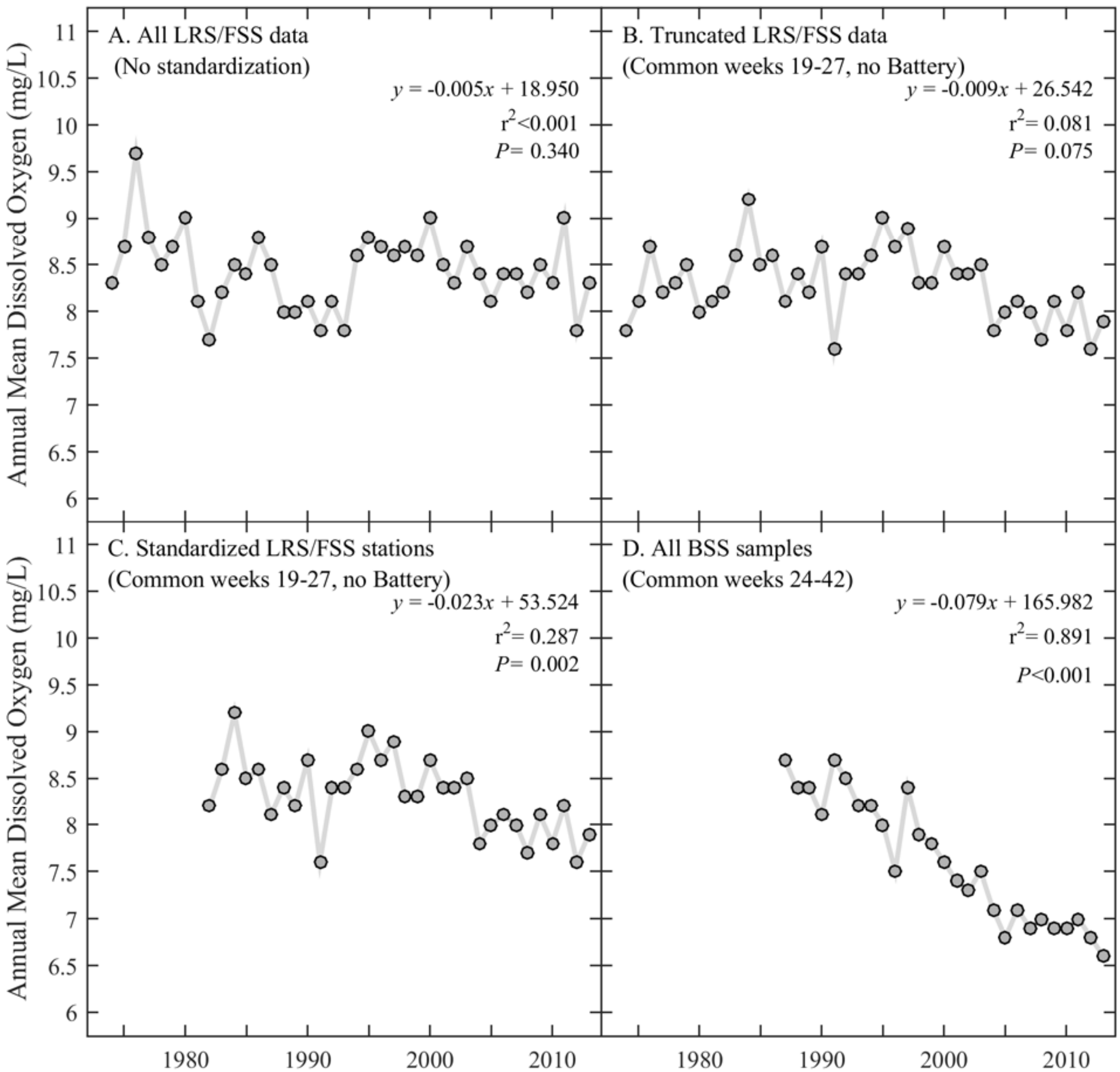


Figure 6. Annual Mean Dissolved Oxygen in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except truncated for consistency in sampled weeks and regions over time; C) LRS/FSS data (Task Code=89 only) collected at the fixed sampling water quality stations standardized for common weeks and regions among years; D) All Beach Seine Survey data during weeks 23-42 representing a common period among the majority of years. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the weekly

averages. ***P* = probability value less than 0.05 considered significant at the 95% confidence level.**

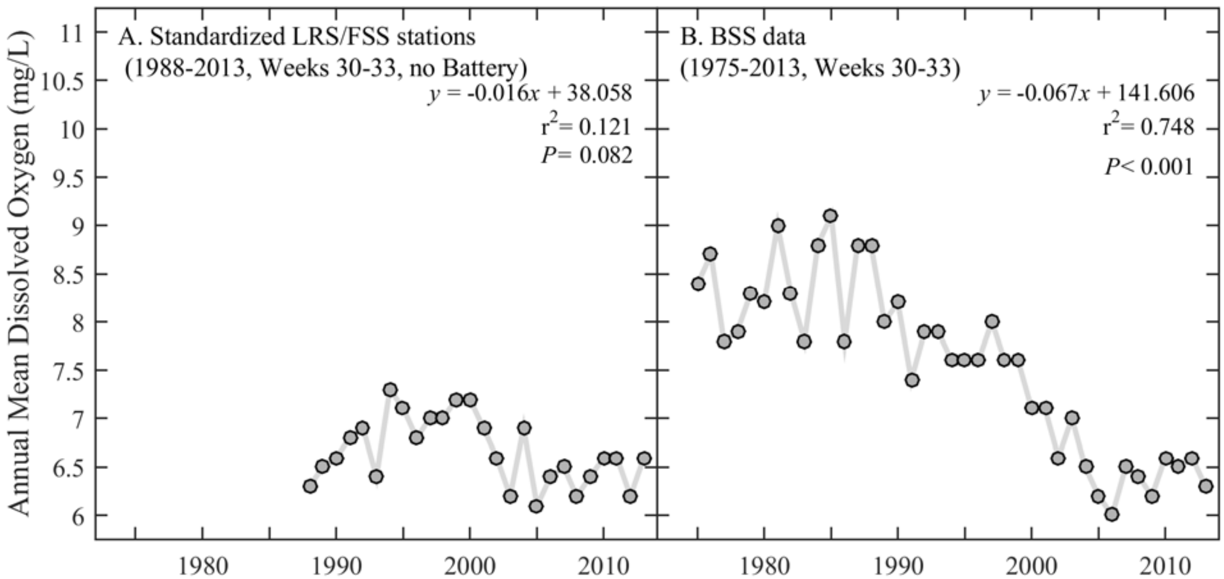


Figure 7. **Annual Mean Dissolved Oxygen Concentration for the Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among all regions from Yonkers to Albany. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the weekly averages. *P* = probability value less than 0.05 considered significant at the 95% confidence level.**

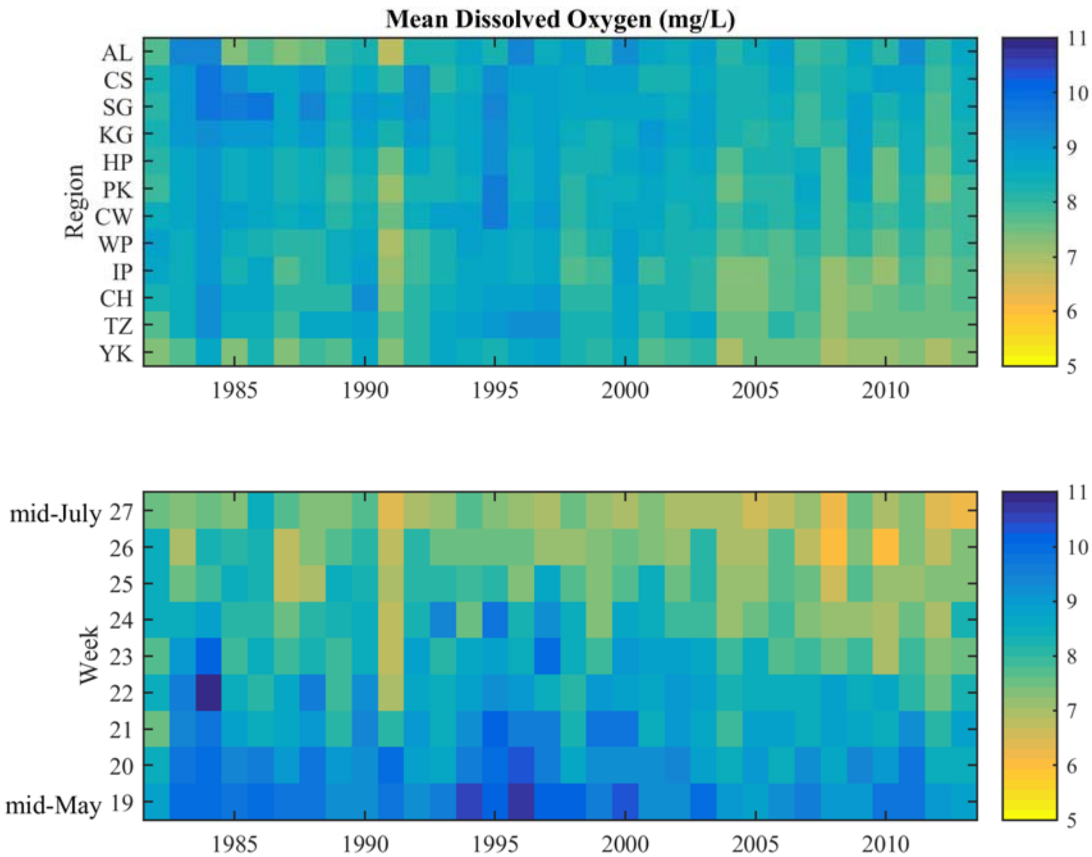


Figure 8. Image plots illustrating the variation in dissolved oxygen concentration by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

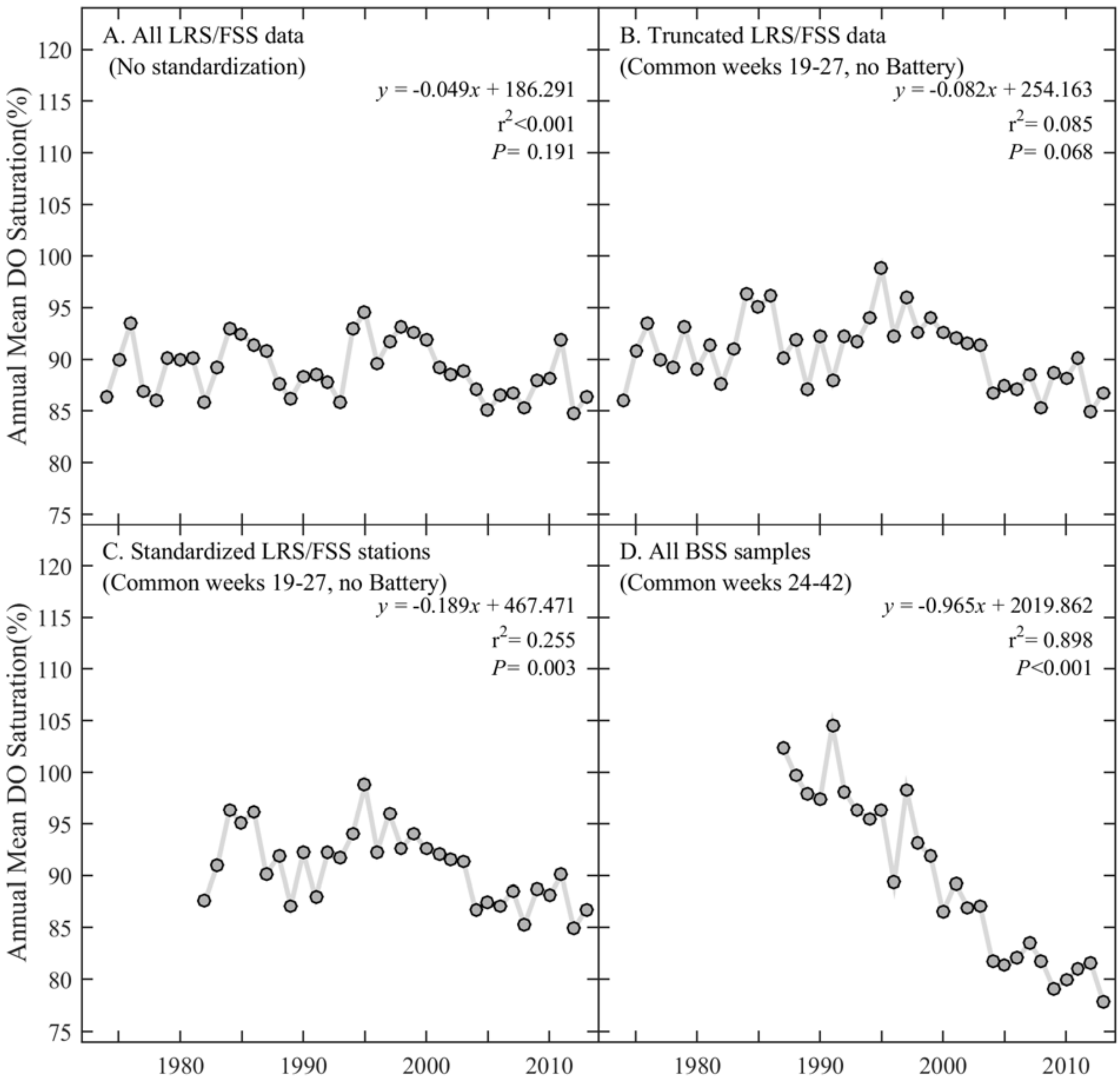


Figure 9. Annual Mean Dissolved Oxygen (DO) Saturation in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except truncated for consistency in sampled weeks and regions over time; C) LRS/FSS data (Task Code=89 only) collected at the fixed sampling water quality stations standardized for common weeks and regions among years; D) All Beach Seine Survey data during weeks 23-42 representing a common period among the majority of years. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the

weekly averages. *P* = probability value less than 0.05 considered significant at the 95% confidence level.

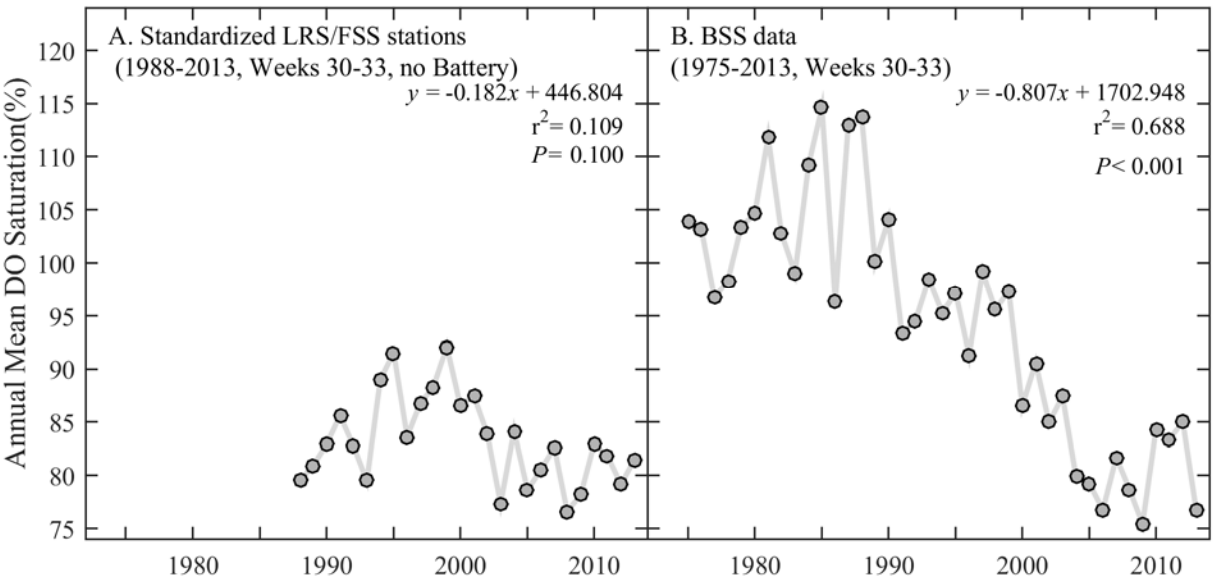


Figure 10. **Annual Mean Dissolved Oxygen Saturation for Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among all regions from Yonkers to Albany. Annual mean was calculated by step 1 - averaging data per region and week and year, step 2- then average all regions per week and year, and step 3 average the weekly averages. *P* = probability value less than 0.05 considered significant at the 95% confidence level.**

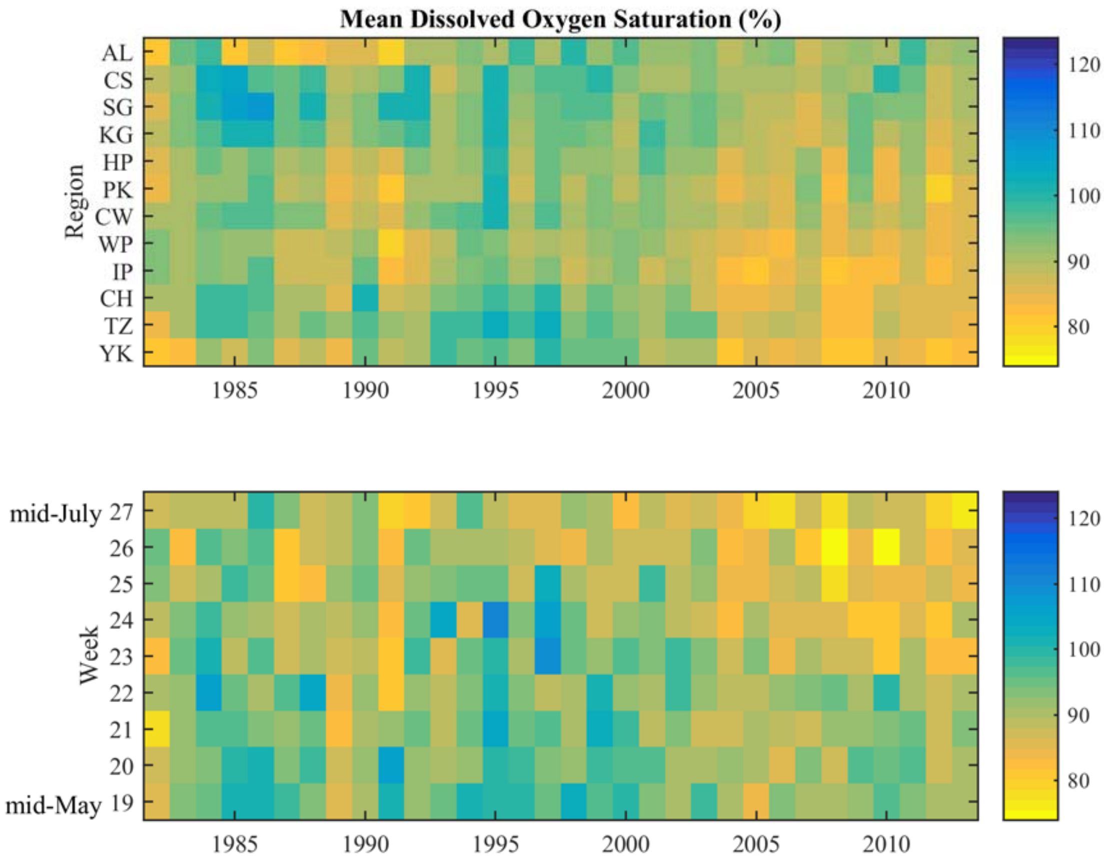


Figure 11. Image plots illustrating the variation in dissolved oxygen saturation by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

Literature Cited

ASA Analysis and Communications. 2015. 2013 Year Class Report for the Hudson River Estuary Monitoring Program. Prepared for Entergy Nuclear Operations Inc., Indian Point Energy Center, 450 Broadway, Suite 1, Buchanan, NY 10511. June 2015.

Benson, B.B., and Krause, D., Jr. 1984. The concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere. Limnology and Oceanography 29: 620–632.

Pisces Conservation Ltd. (Pisces). 2015. The status of fish populations and the ecology of the Hudson. Prepared by Drs. Peter A. Henderson and Richard M.H. Seaby. June 2015.

Appendix F: ASA - Estimate of Salinity in the Hudson River at Indian Point Energy Center

ESTIMATE OF SALINITY IN THE HUDSON RIVER AT INDIAN POINT ENERGY CENTER

ASA Project Number: 2009-167

PREPARED FOR:
Indian Point Energy Center
Buchanan, NY

AUTHORS:
Craig Swanson
Deborah Crowley
Lauren Decker
Nicholas Cohn
Yong Kim

science. services. solutions.

Applied Science Associates, Inc.
55 Village Square Drive
South Kingstown, RI 02879 USA
phone: +1 401 789-6224
fax: +1 401 789-1932

ASA Offices:
São Paulo, Brazil
Shanghai, China
Gold Coast, Australia
Perth, Australia

DATE SUBMITTED
19 November 2010

www.asascience.com

EXECUTIVE SUMMARY

It is necessary to estimate salinity in the Hudson River (River) at the Indian Point Energy Center (IPEC) in order to evaluate environmental effects on air quality during closed cycle cooling operations since make-up water is drawn from the River to replace losses from evaporation, drift and blowdown from the cooling towers. The water quality of the circulating cooling water, measured in part by salinity, is important for use in the design of the cooling tower system to ensure optimal operation and minimal environmental effects on air quality. An analysis of long-term historical measurements of salinity in the River was made to provide an estimate of expected salinity of the makeup water for IPEC.

Direct measurements of salinity are not made at IPEC. Consequently, Applied Science Associates, Inc. (ASA) developed an empirical relationship to estimate salinity at the IPEC intake based on salinity measured at other locations in the River. The data sets used for this analysis consisted of conductivity measurements taken every 15 minutes by the U.S. Geological Survey (USGS) at Hastings-on-Hudson (Hastings), , Tomkins Cove (Tomkins), and West Point. The Hastings station is located 21 mi downstream of IPEC and has been continuously operating since 1992. The West Point station is located 9 mi upstream of IPEC and has been operating since 1991. The Tomkins station was located 1 mi downstream of IPEC, but was discontinued in 2001.

A statistical analysis was performed on the salinity data at each of the USGS stations for the available data. The analysis revealed a decrease in salinity to the north (upriver), from Hastings to Tomkins to West Point. Mean salinity at Hastings was 6.29 psu, Tomkins was 2.09 psu, and West Point was 0.79 psu, consistent with the 90th percentile salinity values of 10.88 psu (Hastings), 4.96 psu (Tomkins) and 2.63 psu (West Point). Hastings and West Point exhibited the lowest salinity, as determined by the mean and 90th percentile values for the periods of record, in April. Low salinity during this time is correlated with high freshwater discharge. The highest mean and 90th percentile values occur in September at these two stations, primarily as a function of lower freshwater discharge. Tomkins, with a significantly shorter period of record, had the lowest average salinity values in January and the highest in August.

A correlation analysis was performed that related the salinity at Tomkins to that at West Point and Hastings. It was found that the West Point data was more highly correlated to Tomkins than Hastings was and therefore used to estimate Tomkins salinity for the long-term decadal period. The model was improved at low salinities by forcing the Tomkins salinity to be equal to the West Point salinity when the Hastings salinity fell below 4.07 psu. This improvement had no effect on higher salinity predictions.

The decadal (2000-2009) salinity time series at IPEC (assumed equivalent to that at Tomkins) was generated to provide a long-term estimate of salinity under a variety of environmental

conditions. This time series is consistent with the analysis period conducted for the extreme environmental conditions in support of the hydrothermal modeling (Swanson et al., 2010).

The model results showed that salinities were typically higher in the summer and fall seasons, consistent with the observations at the USGS stations. Some years (2000, 2001, and 2006) showed extended periods of salinity exceeding 5 psu for three months with peaks exceeding 7 psu. There were also shorter periods when the salinity was zero (2000, 2001, and 2008), usually in the spring season. These variations are primarily due to freshwater entering the River, although there are occasional events (storm surge) that can transport salt from the ocean to the vicinity of the IPEC intake.

A statistical analysis was performed on the hourly-modeled salinity predictions at IPEC for the decadal period 2000 through 2009. The mean salinity over the entire period was 1.80 psu, the minimum 0.07 psu and the maximum 7.67 psu. The median, or 50th percentile, was 0.72 psu, indicating that the salinity distribution is not a normal distribution, but slightly biased to lower salinities. The 90th percentile salinity was 5.23 psu. Salinities between 0 and 0.25 psu were found to occur 30.62% of the time while salinities between 0.25 and 0.50 psu dropped to 12.29% of the time. The large number of low salinities is indicated by the cumulative frequency of occurrence that shows over 50% (54.78%) of the salinities were less than 1.00 psu.

The statistical summary of the 10-yr data set broken down by year showed that 2001 had the highest mean (3.21 psu) and highest median (3.28 psu), 2002 had the highest maximum (7.67 psu) and highest 90th percentile (6.90 psu). Salinities between 0 and 0.25 psu occurred between 12% of the time in 2000 and 42% in 2009 while salinities between 0.25 and 0.50 psu dropped dramatically for all years. The large number of low salinities was indicated by the cumulative frequency of occurrence showed that between 33% (in 2001) and 70% (in 2000) of the salinities are less than 1.00 psu.

The statistical summary of the 10-yr data set broken down by month showed that September had the highest mean (3.84 psu), highest maximum (7.67 psu), highest median (3.70 psu) and highest 90th percentile (7.16 psu), followed by the months of July, August, October and November. The winter and spring months had lower values with April the lowest of any month. Salinities between 0 and 0.25 psu varied between 5% of the time in September and 85% in April, consistent with fluctuations in freshwater discharge to the River. Salinities between 0.25 and 0.50 psu dropped dramatically for most months, indicating an uneven distribution of salinities across the range of values. The large number of low salinities is indicated by the cumulative frequency of occurrence that shows between 18% (in September) and 86% (in April) of the salinities are less than 1.00 psu.

The effect of using linear interpolation to fill the missing hours (2.8% of the total hours) is insignificant when viewed in the context of the 10-yr record as all statistical measures showed a maximum difference of only 0.01 psu when compared to the results of the non-filled data set. The individual years and months exhibited larger differences but were still relatively small.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Entergy Indian Point Energy Center (IPEC), consisting of two operating nuclear power plants (Units 2 and 3), is located along the eastern side of the Hudson River (River) approximately 42 miles upstream of the Battery (located at the southern tip of Manhattan and defined as the mouth of the River) in the Village of Buchanan, New York. IPEC uses a once-through cooling water configuration to cool the system, discharging heated water employed in the cooling process through a discharge canal to the River. The discharge is permitted by the New York State Department of Environmental Conservation (NYSDEC) via a State Pollutant Discharge Elimination System (SPDES) Permit NY0004472. As part of the renewal process NYSDEC directed Entergy to perform a feasibility and alternative technology assessment of the use of closed-loop cooling, i.e., cooling towers.

The purpose of this report is to assess the salinity variation in the waters of the River near IPEC that would be used to supply makeup water to the cooling towers. This makeup water is required to replace water lost by evaporation, drift and blowdown from cooling tower operations. The water quality of the circulating cooling water, measured in part by salinity, is important for use in the design of the cooling tower to ensure optimal operation and minimal environmental effects on air quality. Since the River is an estuary, salt concentration can vary widely based on environmental forcing so that a constant salinity value to assess the environmental effects and plant efficiency is impractical. Therefore, an analysis of historical measurements of salinity from three locations in the River was performed to provide a more appropriate estimate of expected salinity of the makeup water for IPEC.

Direct measurements of salinity are not made at IPEC. Consequently, Applied Science Associates, Inc. (ASA) developed an empirical relationship to estimate salinity entering the IPEC intake based on salinity measured at other locations in the River. The data sets used for this analysis consisted of conductivity measurements taken every 15 min by the U.S. Geological Survey (USGS) at Hastings-on-Hudson (Hastings), Tomkins Cove (Tomkins), and West Point. The Hastings station is located 21 mi downstream of IPEC and has been operating continuously since 1992. The West Point station is located 9 mi upstream of IPEC and has been operating continuously since 1991. The Tomkins station is located 1 mi downstream of IPEC, but was discontinued in 2001. Figure 1 shows the locations of USGS stations in the River relative to IPEC.

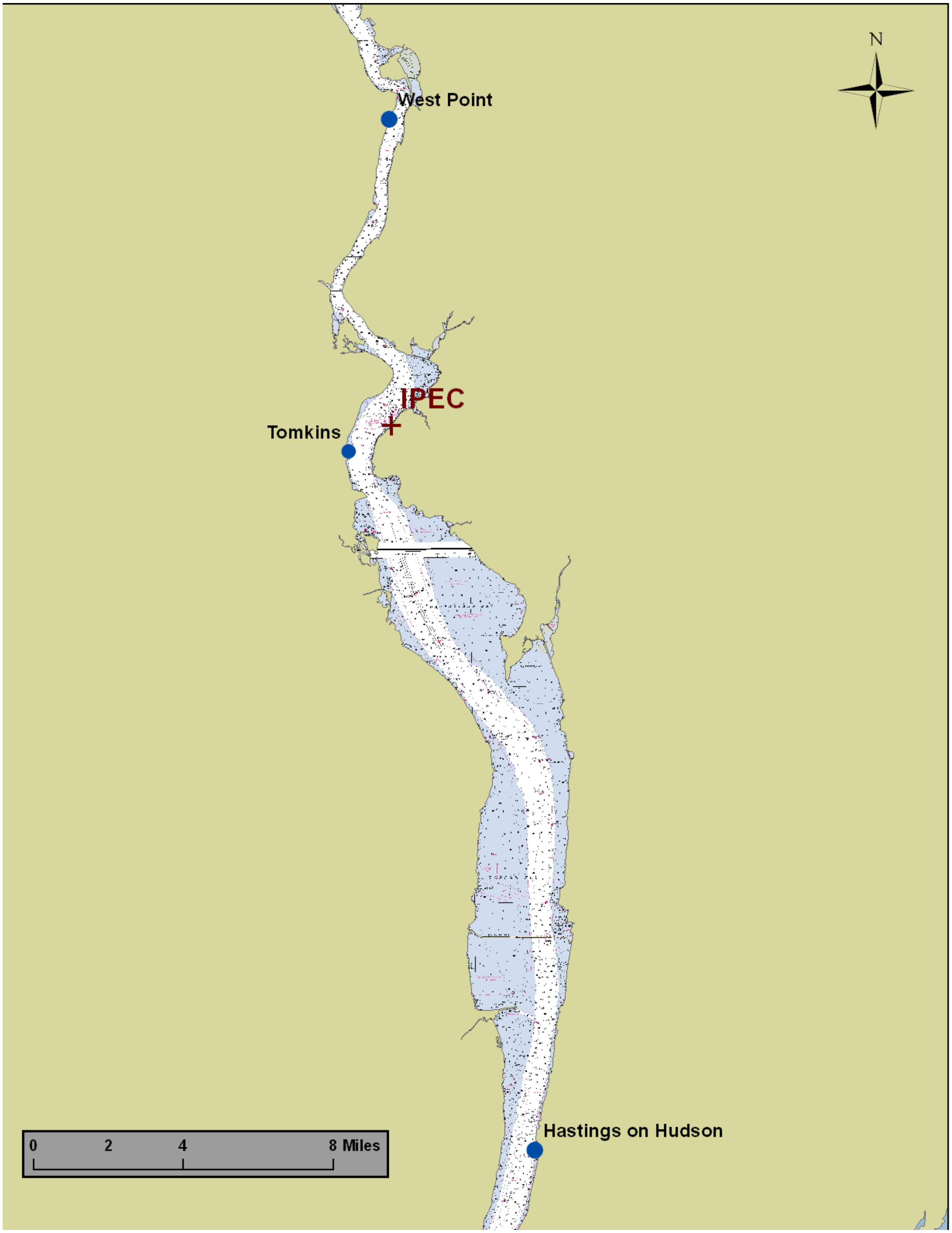


Figure 1-1. Map of a portion of the Hudson River showing the USGS stations used in the present analysis (Hastings, Tomkins, and West Point) in relation to IPEC.

2 USGS DATA

Water level, temperature and specific conductivity data is available in 15-min intervals from two long-term stations located in the River. The Hastings station is located 21 mi downstream from IPEC and West Point is located 9 mi upstream of IPEC (Figure 1-1). These stations provide a continuous long-term history of conductivity variations in the River and, although located some distance from IPEC, the observations bound the range of conductivity (and ultimately salinity) at IPEC. A summary of the stations adapted from the USGS website [http://waterdata.usgs.gov/ny/nwis/rt] is provided below:

- Hastings (USGS station 01376304) located 21 mi above Battery at Lat 40°59'16", Long 73°53'15" referenced to North American Datum of 1927, Westchester County, NY, Hydrologic Unit 02030101, 180 feet from left bank on abandoned Mobil Oil Corporation platform, 0.5 mi southwest of railroad station, at Hastings-on-Hudson. Specific conductivity is measured at a depth of 10 ft below the National Geodetic Vertical Datum of 1929 (approximately mean sea level). Hastings conductivity data is available from 1 October 1999 to the present (real time).

- West Point (USGS station 01374019) located 51 mi above Battery at Lat 41°23'10", Long 73°57'20" referenced to North American Datum of 1927, Orange County, NY, Hydrologic Unit 02020008, on right bank at South Dock at West Point. Specific conductivity is measured at a depth of 10 ft below the National Geodetic Vertical Datum of 1929 (approximately mean sea level). West Point conductivity data is available from 1 October 1998 to the present (real time).

Additional continuous (15-min interval) USGS data from a now-discontinued station (01374349) at Tomkins was obtained for the period from May 1997 through July 2001. Since metadata did not exist for this station, it is assumed that the instrument depth is 10 ft, consistent with other USGS stations. Since Tompkins is located only 1 mi downstream of IPEC (Figure 1-1) at Lat 41°15'31", Long 73°58'41", it is potentially a good proxy for the salinity at the IPEC intake, despite its location on the opposite side of the River.

3 DATA ANALYSIS

The raw specific conductance data, with units of µS/cm at 25 °C, received from USGS consisted of individual readings taken every 15-min. The data was converted to salinity, with units of Practical Salinity Units (psu), using the relationship:

$$\text{Salinity} = -100*\ln(1-(\text{Conductivity}/178500))$$

This equation is based on an analysis conducted by Normandeau Associates, Inc. on properties of water in the River (Texas Instruments, 1976).

The converted salinity data was then filtered with a centered 1-hr moving average and subsampled to every hour. The Tomkins record was analyzed for the period from May 1997 to July 2001. However, longer records were available for the other two USGS stations, so the salinity was analyzed from October 1998 to December 2009 for West Point and from October 1999 to December 2009 for Hastings. The following sections describe the analysis of the individual datasets.

3.1 TOMKINS DATA

The raw specific conductance data received from USGS for the Tomkins station consisted of records every 15-min from 15 May 1997 to 16 July 2001. The data was converted to salinity, filtered with a centered 1-hr moving average and subsampled to an hour. Figure 3-1 displays the time series of the hourly subsampled salinity data. Table 3-1 outlines basic statistics of the Tomkins dataset, broken down by month and year. The data indicates that there is a large range in salinity at Tomkins ranging from 0.09 to 9.27 psu. The maximum salinity reading at Tomkins occurs in August 1999. The mean salinity for the entire record is 2.09 psu and the median (50th percentile) is 1.49 psu. Large difference between the mean and median values indicates that the average is driven up by some high salinity spikes within the river. Additionally, the year-to-year variation is significant with large differences in the 50th and 90th percentile values among the years.

The monthly variation shows lower mean values, between 0.36 and 1.50 psu, from January through June presumably due to increased freshwater discharge. Higher mean values, with a range between 2.56 and 4.07 psu, occur from July through December. Higher salinity is generally indicative of lower freshwater discharge into the River. This general seasonal trend is also apparent in the other statistical measures. For example, the highest 90th percentile values occur in August and September, at 7.22 and 6.49 psu, respectively.

Table 3-1. Statistical summary for the entire Tomkins period of record (15 May 1997 through 16 July 2001) and for each year and month in the record.

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
All	2.09	0.09	9.27	1.49	4.96

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
1997	3.36	0.10	6.71	4.03	5.56
1998	2.12	0.09	6.61	2.04	4.54
1999	2.60	0.13	9.27	1.93	6.54
2000	1.20	0.10	7.99	0.60	3.18
2001	1.29	0.09	6.20	0.74	3.23
Jan	1.47	0.09	4.66	1.31	2.98
Feb	1.24	0.14	4.28	1.11	2.58
Mar	0.92	0.11	7.72	0.18	2.97
Apr	0.36	0.09	2.96	0.17	0.94
May	1.11	0.09	6.20	0.26	3.53
Jun	1.50	0.11	5.27	0.79	3.85
Jul	2.56	0.12	8.25	2.32	5.22
Aug	4.07	0.17	9.27	4.44	7.22
Sep	3.70	0.18	9.00	4.17	6.49
Oct	3.26	0.15	6.68	3.69	5.34
Nov	3.12	0.24	7.99	3.17	5.36
Dec	1.88	0.12	5.90	1.75	3.92

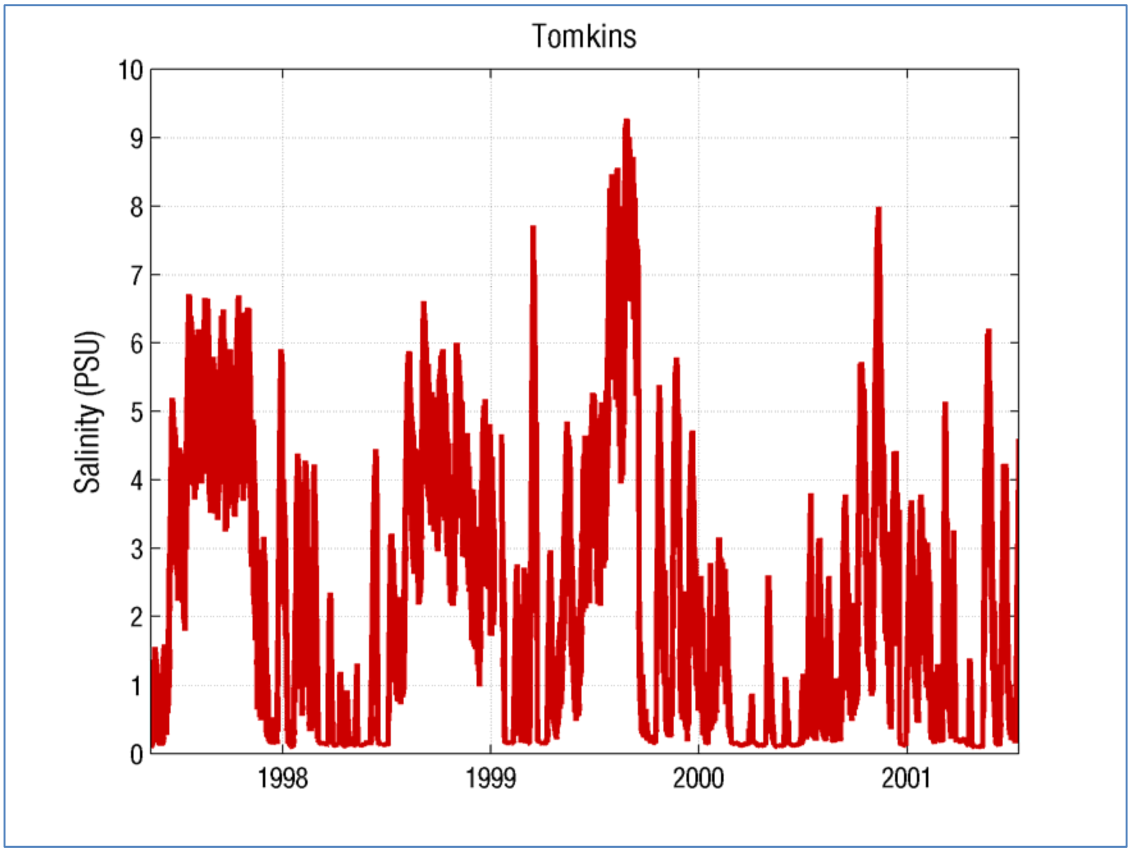


Figure 3-1. Hourly time series at Tomkins for the period of record (15 May 1997 through 16 July 2001).

3.2 HASTINGS AND WEST POINT DATA

The raw specific conductance data received from USGS for the Hastings and West Point stations consisted of observations every 15-min extending from 1 October 1998 to 31 December 2009 for West Point and 1 October 1999 to31 December 2009 for Hastings. The data were converted to salinity, filtered with a centered 1-hr moving average and subsampled to an hour. The period used in the model development and calibration, as described in later sections, extended from 1 October 1999 through 16 July 2001 since this period included all three USGS stations. The period used in the subsequent model predictions was the decade 2000 – 2009, consistent with previous ASA analyses (Swanson et al., 2010).

3.2.1 HASTINGS DATA

The Hastings data is shown in Figure 3-2 with summary statistics given in Table 3-2. The salinity variation at Hastings is substantial, indicative of the dynamic processes occurring in the River estuary. The large range in salinity at the site varies from 0.10 psu to a maximum of 19.06 psu in February 2007. The mean salinity for the entire record is 6.29 psu is close to the median (50th percentile) is 6.12 psu, indicative of a normal distribution. The year-to-year variation for the mean ranges from 4.86 psu in 2000 and 7.77 psu in 2001. The 50th percentile values range from 5.19 psu in 2000 and 7.92 psu in 2001 while the 90th percentile values range from 8.28 psu in 2000 to 12.99 psu in 2002.

The monthly variation mean salinity values are the lowest between December and June, due to increased freshwater discharge into the River. The exception occurs in February when the mean salinity at 6.36psu, far exceeding the mean in the other winter and spring months. Higher mean values, ranging between 6.10 and 9.44 psu, are observed from July through November. This trend is also evident from other statistical measures, including the peak 90th percentile monthly value of 12.84, which occurs in September.

Table 3-2. Statistical summary for the entire Hastings period of record (October 1999 through December 2009) and for each year and month in the record.

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
All	6.29	0.10	19.06	6.12	10.88
1999	5.99	1.30	14.25	5.89	8.47
2000	4.86	0.13	15.02	5.18	8.28
2001	7.77	0.16	15.32	7.92	11.94
2002	7.56	0.72	16.28	7.06	12.99
2003	5.55	0.12	18.50	5.41	9.76
2004	6.59	0.22	16.17	6.48	10.57
2005	6.49	0.12	16.22	6.51	11.29

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
2006	5.75	0.13	15.96	5.67	9.96
2007	7.03	0.12	19.06	7.74	11.04
2008	5.41	0.10	18.43	5.23	10.10
2009	5.94	0.21	14.47	6.02	9.18
Jan	5.36	0.14	16.30	5.34	9.15
Feb	6.36	0.12	19.06	6.53	9.85
Mar	4.92	0.10	15.25	5.19	8.79
Apr	3.43	0.12	13.96	2.87	7.38
May	5.03	0.13	13.97	4.67	8.60
Jun	5.37	0.15	15.84	5.12	8.89
Jul	8.17	0.15	16.28	8.38	11.83
Aug	8.56	1.15	16.02	9.22	12.25
Sep	9.44	0.31	16.28	9.78	12.84
Oct	7.87	0.18	18.43	8.14	11.90
Nov	6.10	0.13	14.49	6.02	10.46
Dec	4.96	0.13	14.47	4.88	8.98

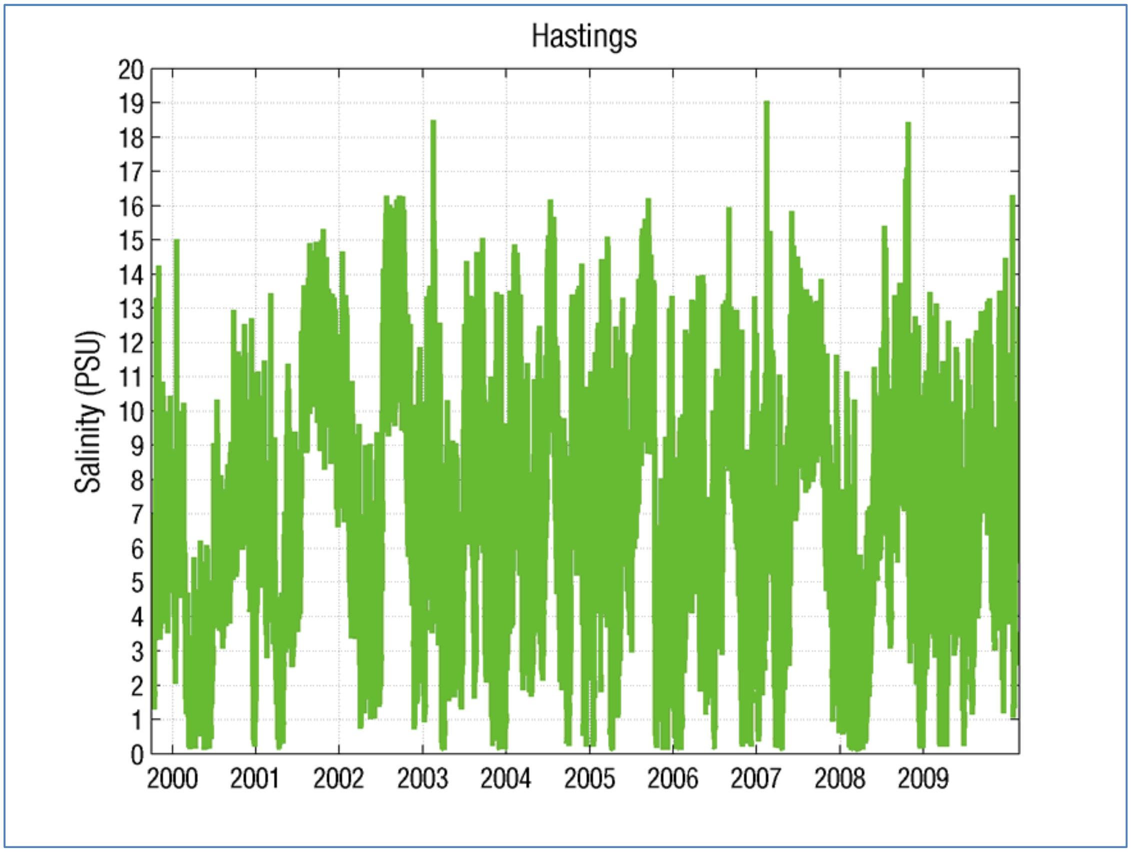


Figure 3-2. Hourly time series at Hastings for the period from 1 October 1999 through 31 December 2009.

3.2.2 WEST POINT DATA

The West Point data is shown in Figure 3-3 with summary statistics given in Table 3-3. There is a lower observed salinity variation at West Point relative to the other two USGS stations simply due to its upstream location. The range in salinity at the site varies from 0.07 psu to a maximum of 6.99 psu, which occurs in September of 2003. The mean salinity for the entire record is only 0.79 psu and the median (50th percentile) is 0.17 psu. The year-to-year variation for the mean ranges from 0.36 psu in 2009 and 1.57 psu in 2001. The 50th percentile ranges from 0.13 psu in 2006 and 1.17 psu in 1998 while the 90th percentile values range from 0.54 psu in 2003 to 4.21 psu in 2006.

The monthly variation shows lower means, between 0.19 and 0.78 psu, from December through June, due to increased freshwater discharge into the River with higher means, between 0.78 and 2.03 psu, from July through November indicative of lower discharge. This trend is also generally seen in the other statistical measures such as with the highest 90th percentile value of 4.70 psu occurring in September.

Table 3-3. Statistical summary for the entire West Point period of record (October 1998 through December 2009) and for each year and month in the record.

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
All	0.79	0.07	6.99	0.17	2.63
1998	1.22	0.22	3.06	1.17	2.12
1999	1.03	0.10	6.08	0.34	3.49
2000	0.39	0.10	5.73	0.14	1.00
2001	1.57	0.09	5.29	1.05	3.64
2002	1.44	0.09	6.99	0.37	4.21
2003	0.27	0.10	2.45	0.16	0.54
2004	0.44	0.10	3.24	0.16	1.28
2005	0.77	0.10	4.39	0.20	2.47
2006	0.38	0.08	3.62	0.13	1.14
2007	1.39	0.08	6.94	0.37	3.91
2008	0.59	0.07	4.73	0.15	1.72
2009	0.36	0.10	3.12	0.14	0.99
Jan	0.41	0.08	3.95	0.15	1.14
Feb	0.49	0.10	4.16	0.18	1.35
Mar	0.37	0.10	3.75	0.16	1.08
Apr	0.19	0.08	1.99	0.13	0.29
May	0.33	0.07	3.84	0.12	1.03
Jun	0.42	0.10	3.36	0.14	1.16
Jul	1.03	0.08	4.74	0.60	2.67
Aug	1.77	0.09	6.08	1.36	3.98
Sep	2.03	0.11	6.99	1.44	4.70
Oct	1.37	0.11	6.64	0.68	3.65
Nov	0.78	0.09	5.73	0.21	2.40

Period	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
Dec	0.46	0.09	4.70	0.14	1.46

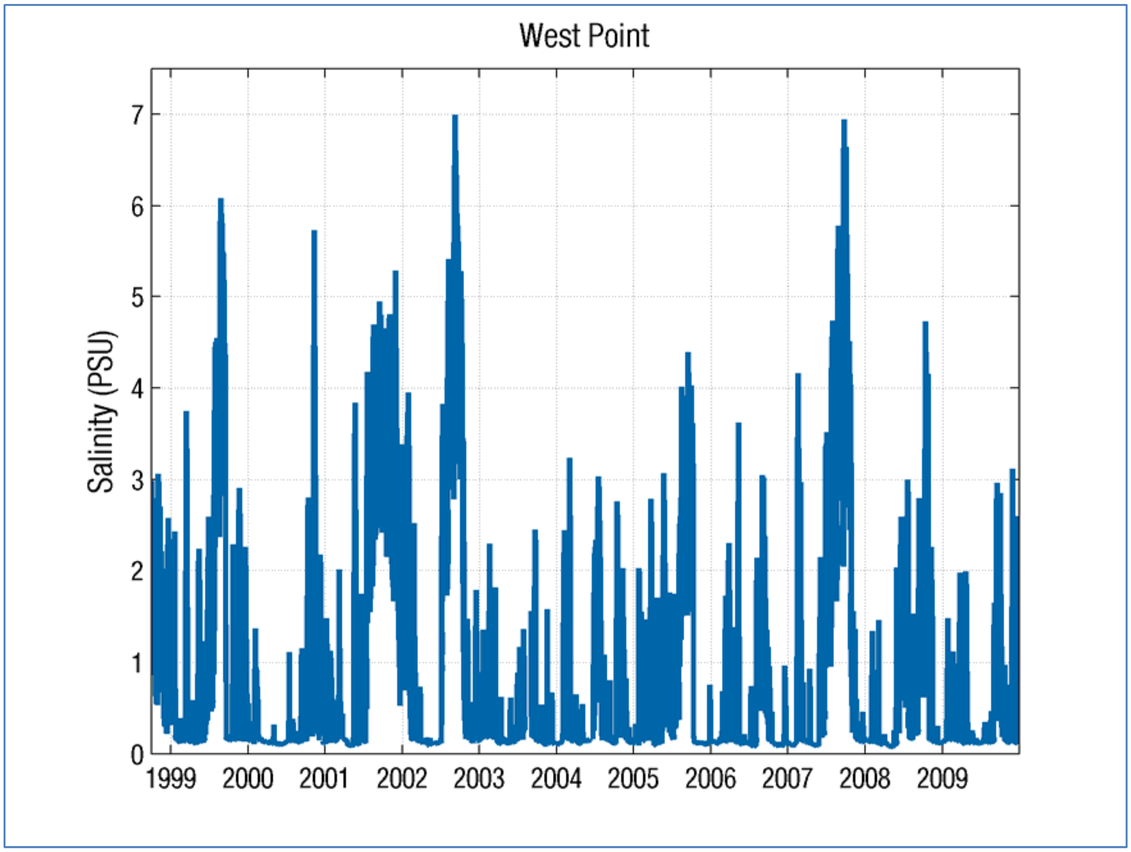


Figure 3-3. Hourly time series at West Point for the period from 1 October 1998 through 31 December 2009.

4 IPEC SALINITY MODEL DEVELOPMENT

To estimate the long-term salinity variation in the River at Tomkins (near IPEC), statistical correlations were developed among the USGS station data. An analysis was conducted examining the correlation between both Tomkins and West Point and Tomkins and Hastings USGS stations to assess the relationships among the stations.

4.1 TOMKINS VS. HASTINGS SALINITY CORRELATION

Figure 4-1 shows a scatterplot of the salinities at Tomkins versus Hastings during the October 1999 through July 2001 period when all three data sets overlapped. There is a large variation of salinity at Hastings (0 – 8 psu) when that observed at Tomkins is small (~0.1 psu). However, there is also large variation at Tomkins (0 – 6 psu) when the salinity at Hastings is fixed at 8 psu. The visual best-fit line to the data is a least squares fitted power-law function, as shown superimposed over the data on Figure 4-1. The power-law function has a variance of 0.66 psu^2 and a standard deviation of 0.81 psu.

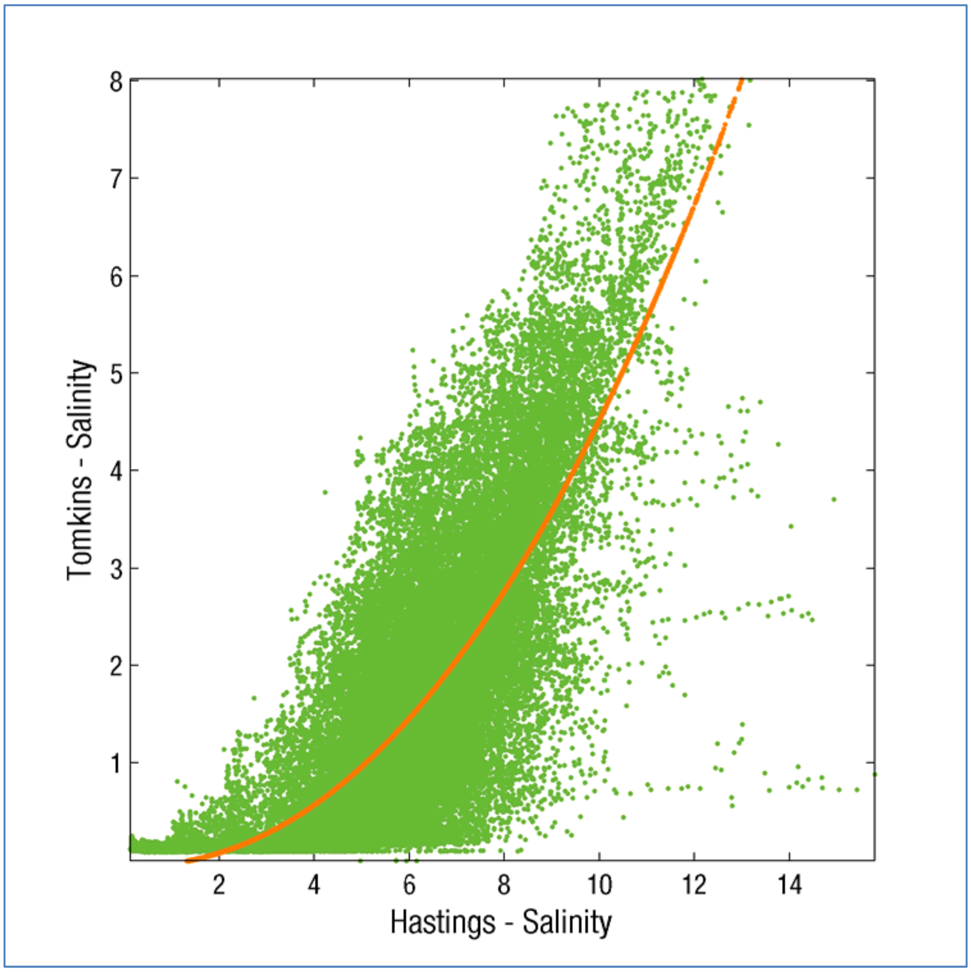


Figure 4-1. Scatterplot of salinity data for USGS stations at Tomkins and Hastings with a power law regression superimposed on the data.

An alternative empirically based approach uses a non-continuous binned relationship between the mean values of salinity at Tomkins averaged over a small range of salinities (the bin width) at Hastings. The bins vary in width from a minimum of 0.084 psu at lowest salinities to a maximum of 0.764 psu at higher salinities (i.e., >5 psu) and are summarized in Table 4-1. The new empirically derived line is superimposed over the data in Figure 4-2. The scatter or fit to the empirical binned function has a variance of 0.60 psu^2 and a standard deviation of 0.78 psu. This new method results in a lower standard deviation and thus a "better fit" as compared to the power law function shown in Figure 4-1. The improvement is seen at the higher Hastings salinities where the Tomkins to Hastings ratio salinity slope decreases to account for the larger scatter in the data.

Table 4-1. Empirically based bin information for Hastings salinity data.

Bin Number	Bin Width (psu)	Bin Max (psu)
1	0.084	0.084
2	0.044	0.128
3	0.059	0.187
4	0.138	0.325
5	0.153	0.478
6	0.187	0.664
7	0.227	0.892
8	0.252	1.144
9	0.304	1.448
10	0.327	1.775
11	0.373	2.148
12	0.420	2.568
13	0.447	3.015
14	0.510	3.525
15	0.537	4.062
16	0.506	4.568
17	0.764	5.332
18	0.406	5.738

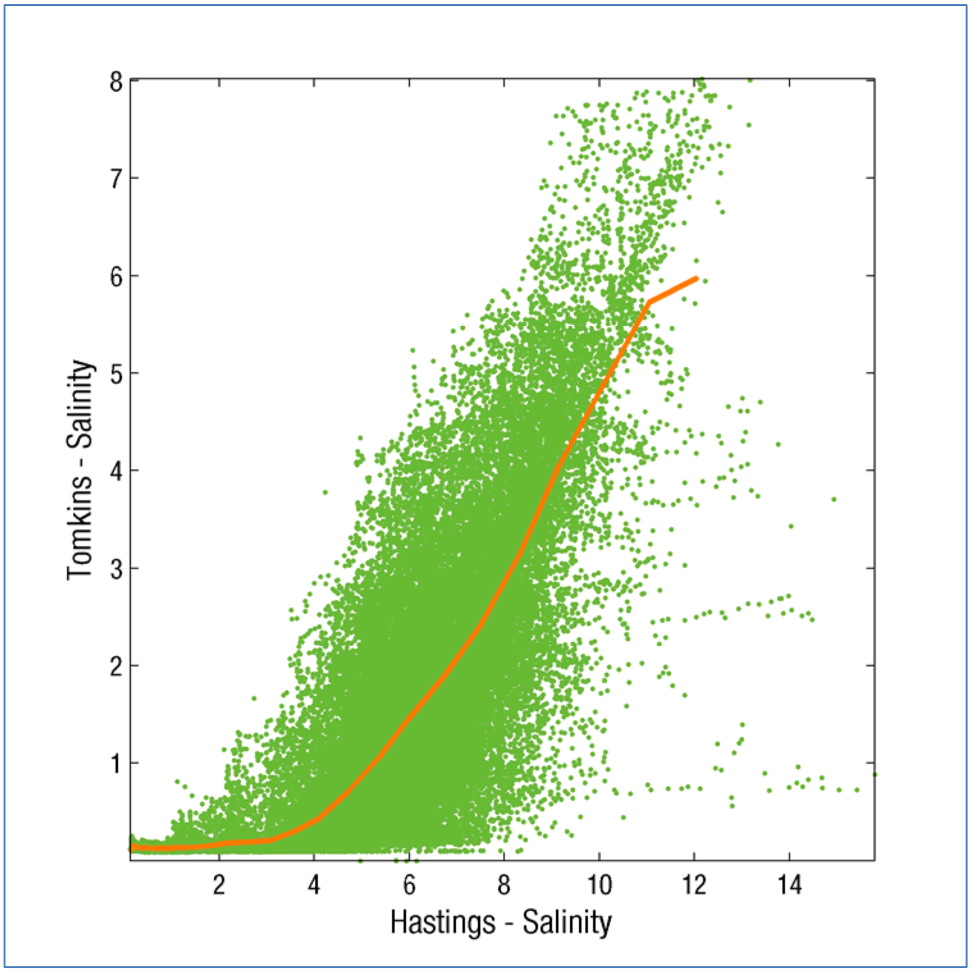


Figure 4-2. Scatterplot of salinity data for USGS stations at Tomkins and Hastings with an empirically based regression superimposed on the data.

4.2 Tomkins vs. West Point Salinity Correlation

The scatterplot of Tomkins versus West Point is shown in Figure 4-3 with the superimposed least squares fitted power-law function. The scatter is much smaller than Hastings as indicated by the variance of 0.23 psu^2 (standard deviation of 0.48 psu). To check the empirically based approach used above, the mean value of salinity at Tomkins was averaged over a small range of salinities (the bin width) at West Point (Figure 4-4). The bins vary in width from a minimum of 0.145 psu at lowest salinities to a maximum of 0.994 psu at the highest salinities (i.e., 11.5 psu) and are summarized in Table 4-2. The scatter is much smaller than at Hasting as indicated by the low variance of 0.18 psu^2, corresponding to a standard deviation of 0.43 psu.

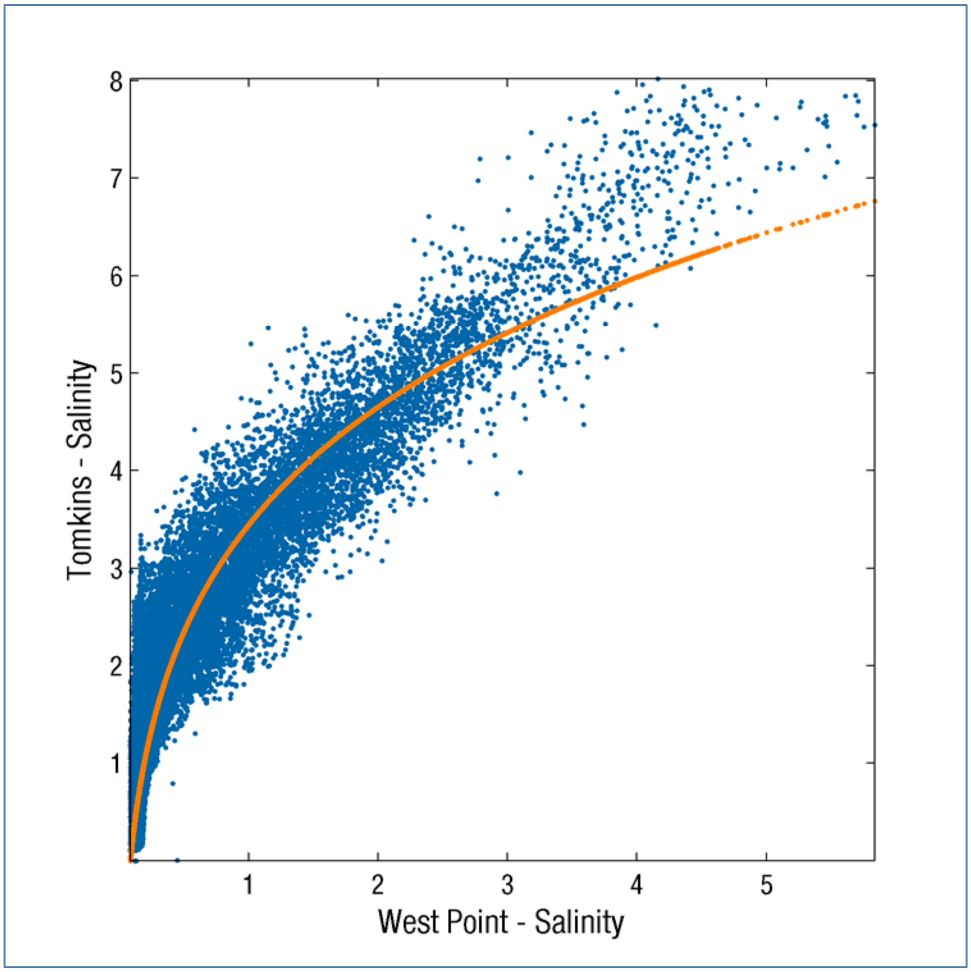


Figure 4-3. Scatterplot of salinity data for USGS stations at Tomkins and West Point with a power law regression superimposed on the data.

Table 4-2. Empirically based bin information for West Point salinity data.

Bin Number	Bin Width (psu)	Bin Max (psu)
1	0.145	0.145
2	0.043	0.187
3	0.141	0.328
4	0.154	0.482
5	0.185	0.667
6	0.230	0.897
7	0.262	1.159
8	0.282	1.441
9	0.344	1.785
10	0.375	2.160
11	0.425	2.585
12	0.479	3.064
13	0.497	3.560
14	0.547	4.107

Bin Number	Bin Width (psu)	Bin Max (psu)
15	0.592	4.699
16	0.633	5.332
17	0.665	5.998
18	0.723	6.721
19	0.774	7.494
20	0.833	8.327
21	0.826	9.153
22	0.940	10.093
23	0.953	11.046
24	0.994	12.040

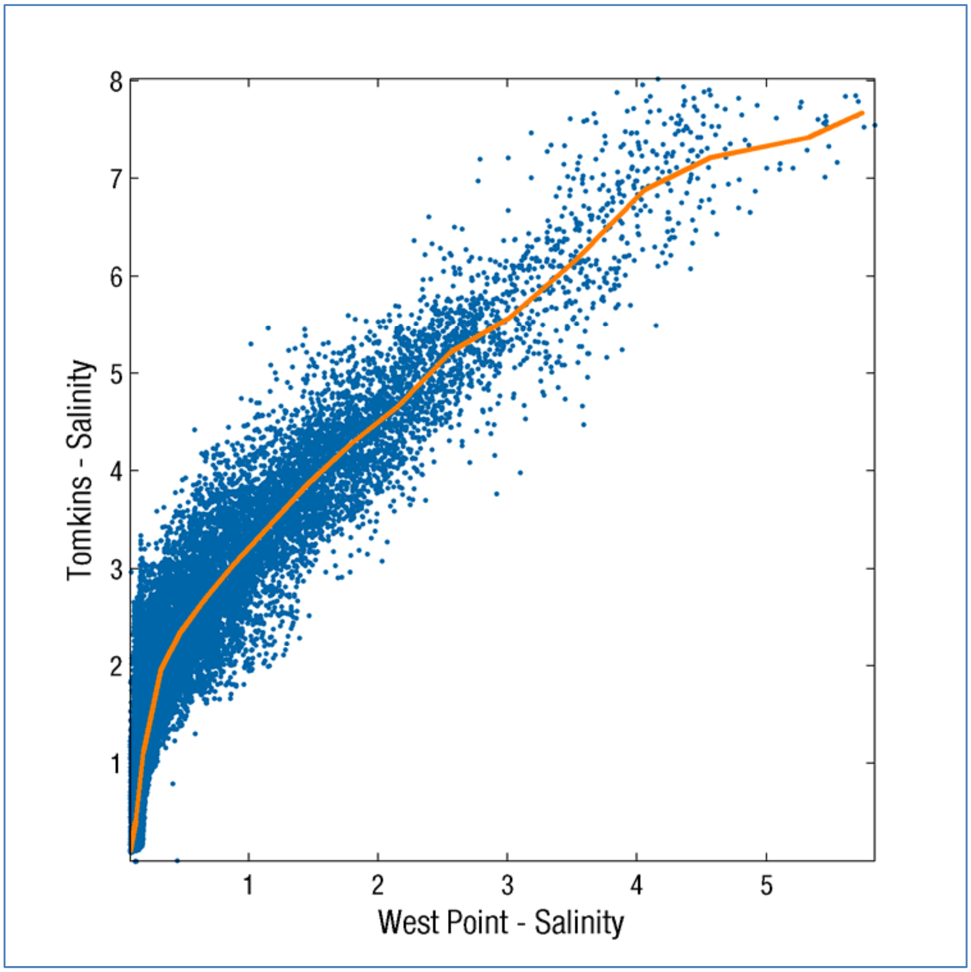


Figure 4-4. Scatterplot of salinity data for USGS stations at Tomkins and West Point with an empirically based regression superimposed on the data.

4.3 IPEC MODEL RESULTS

Since the Tomkins salinity is well correlated to West Point but not to Hastings, initially only the West Point data was used in estimating Tomkins salinity. However, a comparison of the estimated salinity from the empirically based regression model compared to the observed indicates that when salinities are low at West Point (< 1 psu) the model over predicts Tomkins salinities. However, further testing and analysis showed that, when the salinity at Hastings fell below 4.07 psu, the salinity at both West Point and Tomkins was typically very close to zero. Therefore, in all periods when the Hastings salinity dropped below 4.07psu the Tomkins statistical model was set equal to the West Point salinity. This process prevented unreasonably high model predictions of salinity at Tomkins.

Figure 4-5 shows the salinity time series during the period when salinity observations were reported for all three USGS stations, October 1999 through July 2001. As expected, West Point always had the lowest salinity at any given time, Tomkins salinity was essentially the same or higher than West Point salinity, and Hastings consistently had the highest salinity. During high discharge periods, the salinity recorded at Hastings was very close to that observed at Tomkins and West Point. The empirical model estimate at Tomkins is also shown in Figure 4-5 and tracks the observed data at Tomkins closely.

To see how well the empirical model correlated with the observations on shorter time scales, Figure 4-6 displays a segment of the time series from 30 January through 9 April 2000. During the first month of the period, Hastings salinity is greater than 4.07 psu and the model tracks the Tomkins salinity data well. For the rest of the period the Hastings salinity frequently falls below 4.07 psu and the West Point salinity is essentially zero, thus the model forces the Tomkins salinity to the West Point value. This assumption typically works well except that some small excursions of Tomkins salinity are not captured during this period (e.g., early in March) or that extraneous small (<1 psu) levels are intermittently predicted (early February).

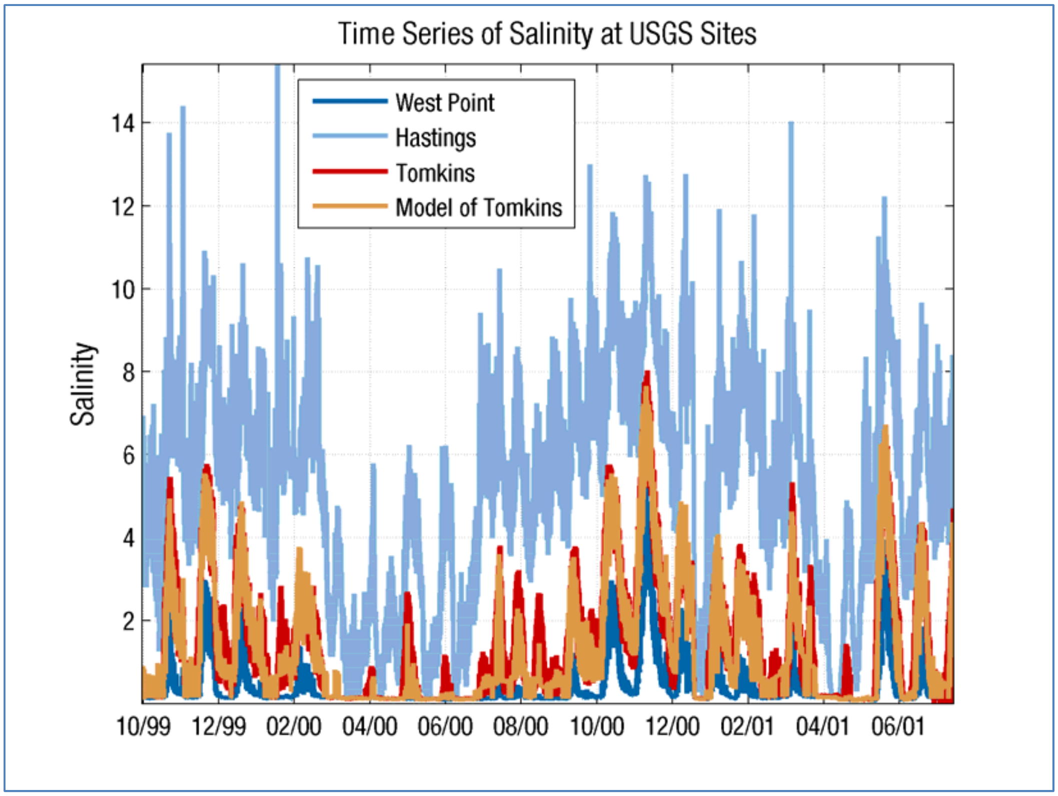


Figure 4-5. Salinity time series of period of record (October 1999 through July 2001).

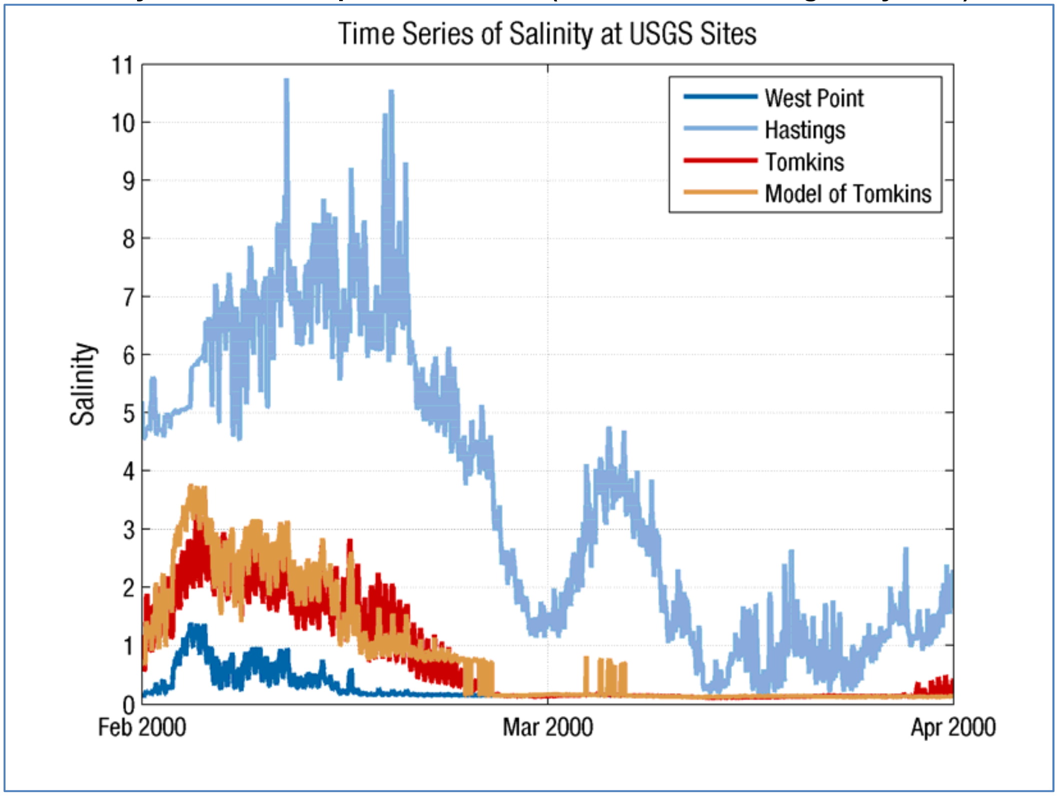


Figure 4-6. Salinity time series of short portion of record (30 January through 9 April 2000) showing ability of model to simulate low salinities at Tomkins.

The resulting time series of hourly salinity at Tomkins, used as a proxy for the IPEC intake, is shown in Figure 4-7 for the 10-year period 2000 – 2009. There is no clear annual cycle although salinities are typically higher in the summer and fall seasons. Some years (2001, 2002, 2005, and 2007) show extended periods of salinity continuously exceeding 4 psu for more than two months with peaks exceeding 7 psu. These variations are primarily due to freshwater entering the River, although there are sometimes events (storm surge) that can transport salt from the ocean to the vicinity of the IPEC intake. The complete 1-hr empirically calculated salinity data set for the 10-yr period is available upon request as an Excel spreadsheet.

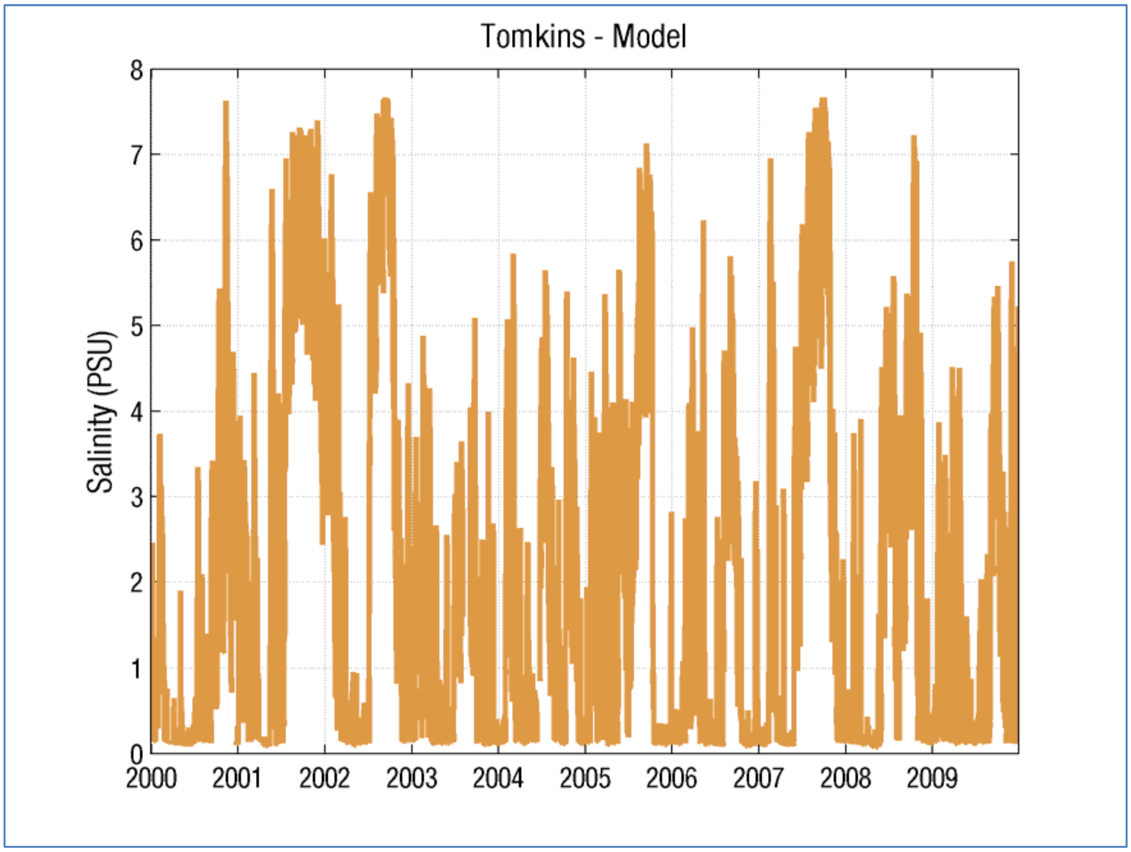


Figure 4-7. Predicted salinity at IPEC (using Tomkins as a proxy) for the period 2000 through 2009.

5 STATISTICAL ANALYSES

Statistics, frequency and cumulative frequency distributions were determined for the hourly-modeled salinity predictions at IPEC (with Tomkins as a proxy) for the decadal period 2000 through 2009. Separate analyses are reported for the entire period, for each of the 10 years and each of the 12 months in the record.

5.1 ENTIRE 2000-2009 ANALYSIS

There were a total of 85,192 hours of data contained in the decadal record (Table 5-1). This value falls below the full 87,672 hours that fall within the period of record from 2000 to 2009 due to a number of missing data points. The missing data points in the original USGS records are likely a function of instrument malfunction, interference, or maintenance.

The mean salinity is seen to be 1.80 psu, the minimum 0.07 psu and the maximum 7.67 psu. The median, or 50th percentile, is 0.72 psu, indicating that the salinity distribution is not a normal distribution, but slightly biased to lower salinities. The 90th percentile salinity, which means that 90% of the salinity values in the record are less than 5.23 psu, while 10% are greater.

Table 5-1. Statistical summary for the entire 10-yr record.

Period	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
2000-2009	85,192	1.80	0.07	7.67	0.72	5.23

Figure 5-1 and Table 5-2 document the frequency and cumulative frequency distribution of the entire 10-yr data set. The salinity bin resolution is 0.25 psu (0 – 0.25, 0.25 – 0.50, 0.50 – 0.75, etc). Salinities between 0 and 0.25 psu occur 30.62% of the time while salinities between 0.25 and 0.50 psu drop to 12.29% of the time. The large number of low salinities is indicated by the cumulative frequency of occurrence that shows over 50% (54.78%) of the salinities are less than 1.00 psu. There are no salinity bins above 1.00 psu exceeding a frequency of 3%.

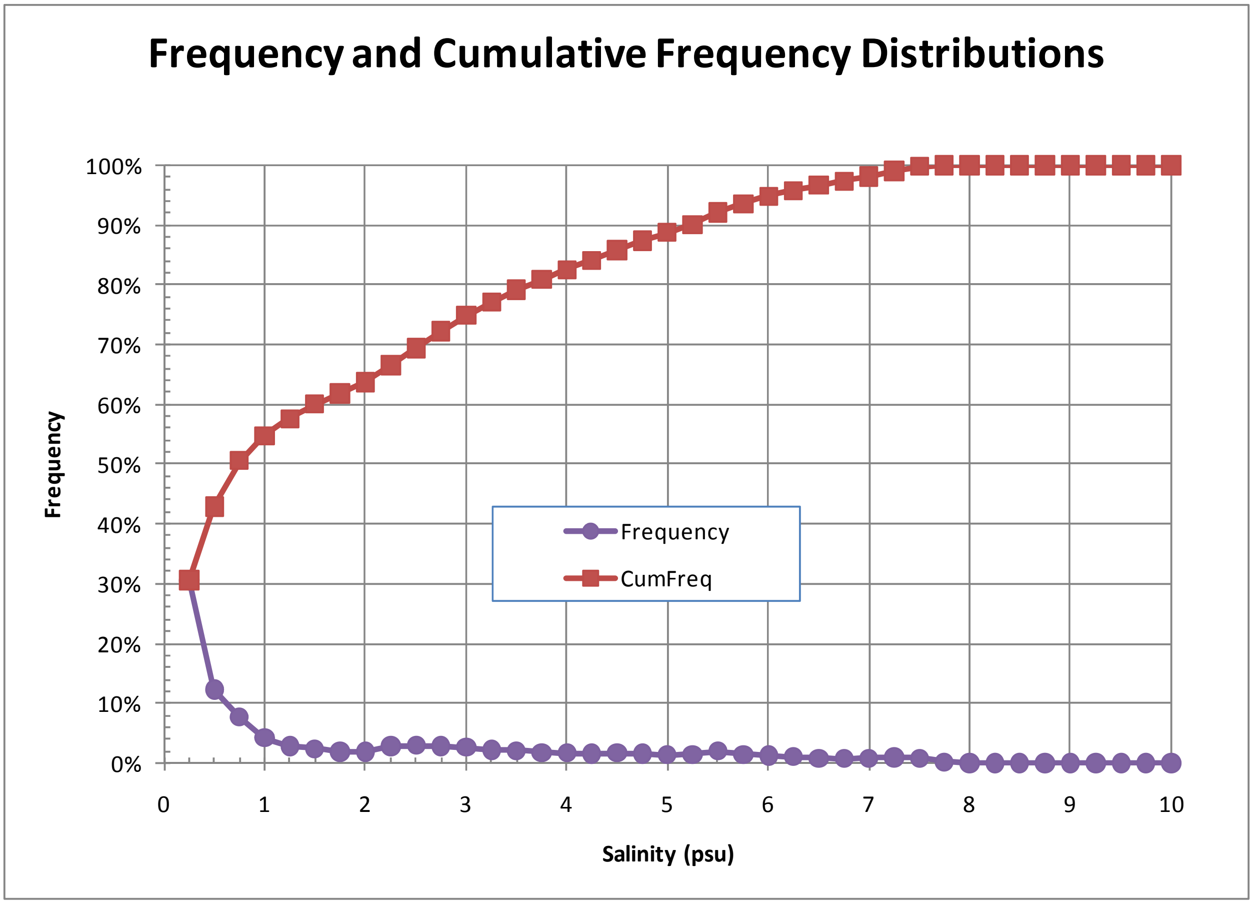


Figure 5-1.Frequency and cumulative frequency distributions for the entire 10-yr record.

Table 5-2. Frequency and cumulative frequency distributions in 0.25 psu bins for the entire 10-yr record.

Minimum Salinity (psu)	Maximum Salinity (psu)	Frequency (%)	Cumulative Frequency (%)
0.00	0.25	30.62%	30.62%
0.25	0.50	12.29%	42.91%
0.50	0.75	7.68%	50.59%
0.75	1.00	4.20%	54.78%
1.00	1.25	2.85%	57.63%
1.25	1.50	2.35%	59.98%
1.50	1.75	1.83%	61.81%
1.75	2.00	1.89%	63.70%
2.00	2.25	2.79%	66.49%
2.25	2.50	2.91%	69.40%
2.50	2.75	2.83%	72.23%
2.75	3.00	2.64%	74.88%
3.00	3.25	2.21%	77.09%
3.25	3.50	2.04%	79.13%
3.50	3.75	1.74%	80.87%

Minimum Salinity (psu)	Maximum Salinity (psu)	Frequency (%)	Cumulative Frequency (%)
3.75	4.00	1.69%	82.56%
4.00	4.25	1.57%	84.13%
4.25	4.50	1.64%	85.77%
4.50	4.75	1.58%	87.35%
4.75	5.00	1.36%	88.71%
5.00	5.25	1.41%	90.12%
5.25	5.50	1.97%	92.10%
5.50	5.75	1.45%	93.55%
5.75	6.00	1.24%	94.79%
6.00	6.25	0.99%	95.78%
6.25	6.50	0.82%	96.60%
6.50	6.75	0.70%	97.30%
6.75	7.00	0.76%	98.07%
7.00	7.25	0.95%	99.02%
7.25	7.50	0.77%	99.79%
7.50	7.75	0.21%	100.00%
7.75	8.00	0.00%	100.00%
8.00	8.25	0.00%	100.00%

5.2 Yearly Analysis for Each Year in 10-yr Record

The statistical summary of the 10-yr data set broken down by year is presented in Table 5-3 and displayed in Figure 5-3. Counts for each year vary from 7,846 (2003) to 8,759 (2001) indicating which years have missing data. Non-leap years have 8,760 hrs while leap years have 8,784 hrs. The data shows that the years 2001, 2002, and 2007 have higher salinities on average, while the years 2000, 2003, and 2009 generally have lower salinities. Highest maximum salinities across the entire data set occur in 2000, 2001, 2002 and 2007, with all exceeding 7.40 psu. The minimum salinities vary for all years between 0.07 and 0.11 psu. The mean is consistently greater than or equal to the median indicating that there are more lower values than higher values. The 90th percentile salinities show values greater than 6 psu during 2001, 2002 and 2007.

Table 5-3. Statistical summary for each year of the 10-yr record.

Period	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
2000	8692	1.10	0.10	7.63	0.52	3.20
2001	8759	3.21	0.09	7.40	3.28	6.32
2002	8572	2.75	0.09	7.67	1.94	6.90
2003	7846	0.97	0.10	5.08	0.52	2.46
2004	8458	1.37	0.11	5.84	0.69	3.60
2005	8486	1.96	0.10	7.13	1.10	5.10
2006	8435	1.16	0.08	6.23	0.38	3.43

2007	8705	2.71	0.08	7.67	2.06	6.60
2008	8501	1.56	0.07	7.23	0.55	4.22
2009	8738	1.15	0.11	5.76	0.45	3.19

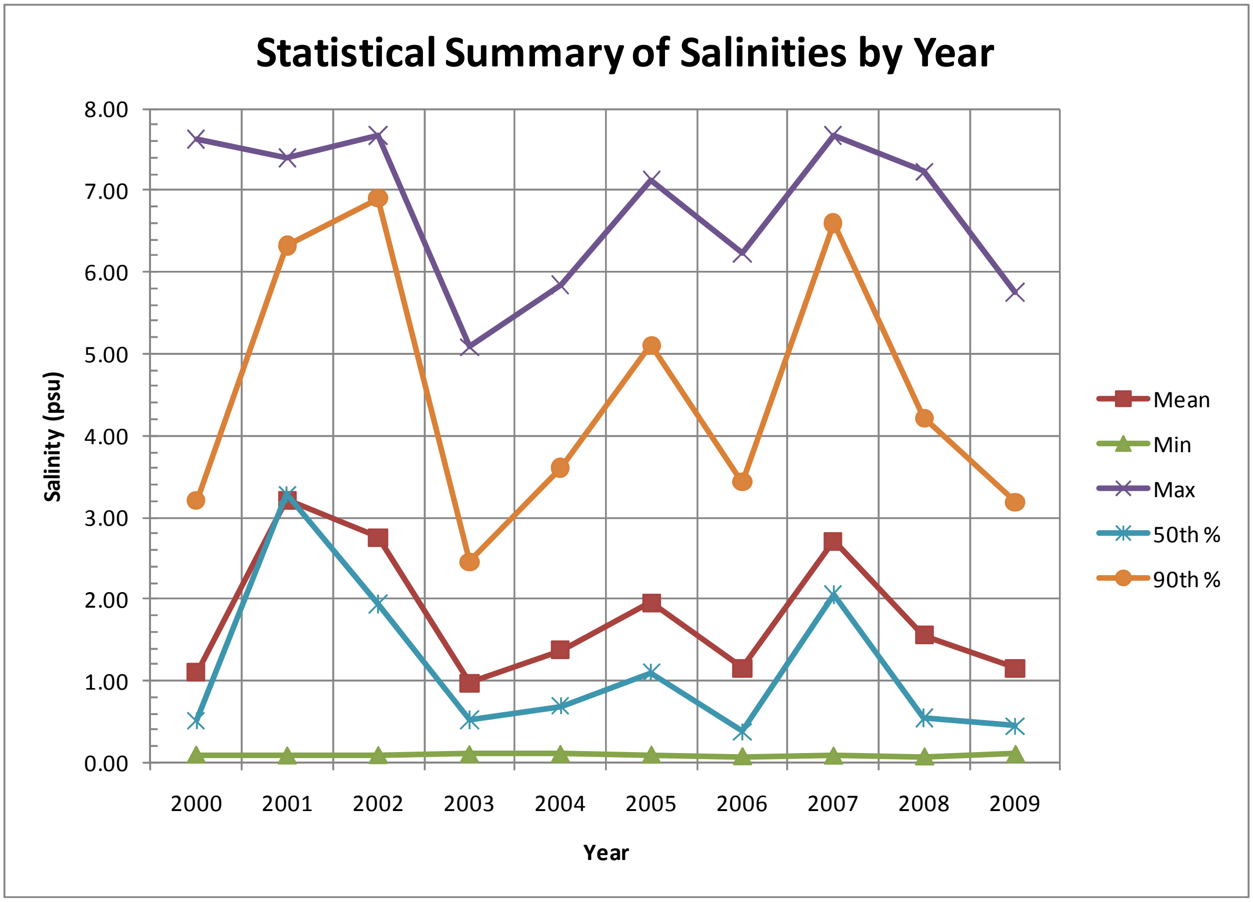


Figure 5-2. Statistical summary by year for the 10-yr period.

Figures 5-3 and 5-4 show the frequency distribution and cumulative frequency distribution, respectively for each year in the 10-yr record. Salinities between 0 and 0.25 psu occur 12% of the time in 2000 and 42% in 2009, while salinities between 0.25 and 0.50 psu occur even less often for all years. Above 1.5 psu, no salinity bins exceed a frequency greater than 5% except for 2009 between 5.50 psu and 6.00 psu. Cumulative frequency distributions indicate that between 33% (in 2001) and 70% (in 2000) of the salinities are less than 1.00 psu.

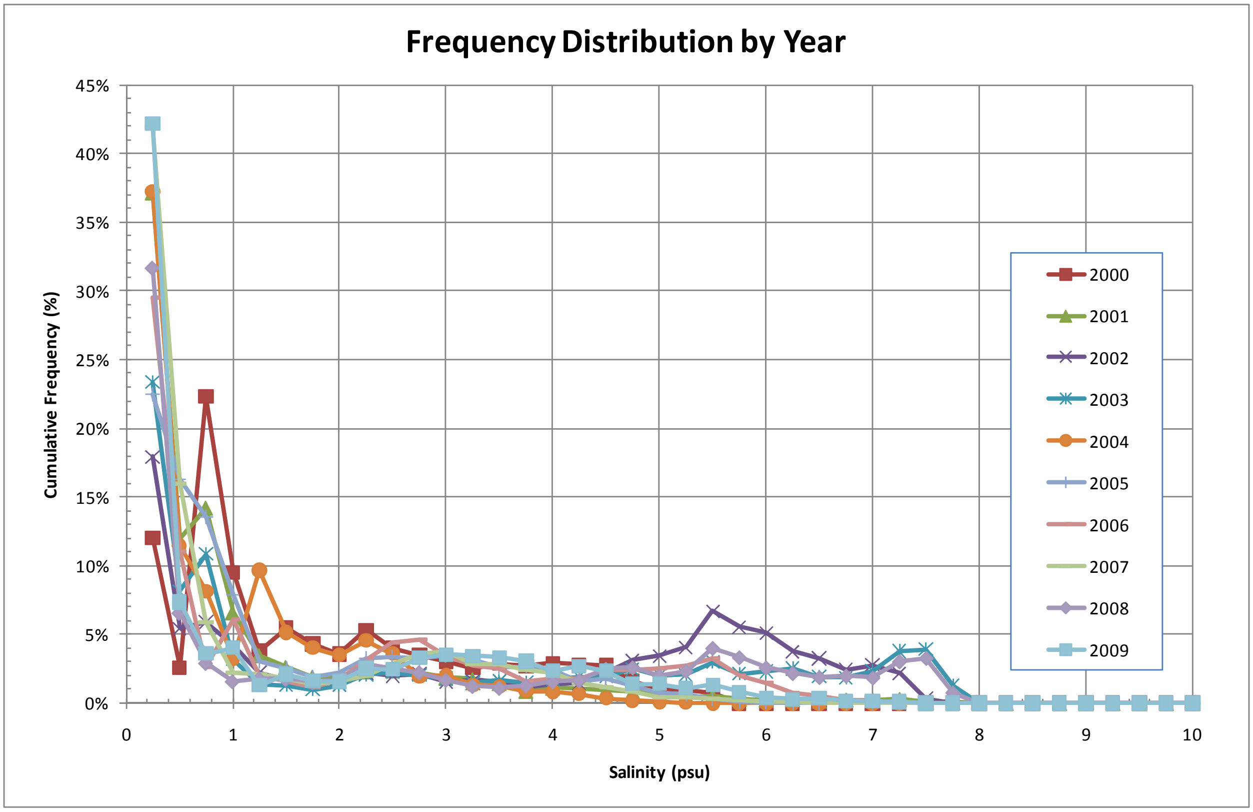


Figure 5-3. Frequency distributions for each year of the 10-yr record.

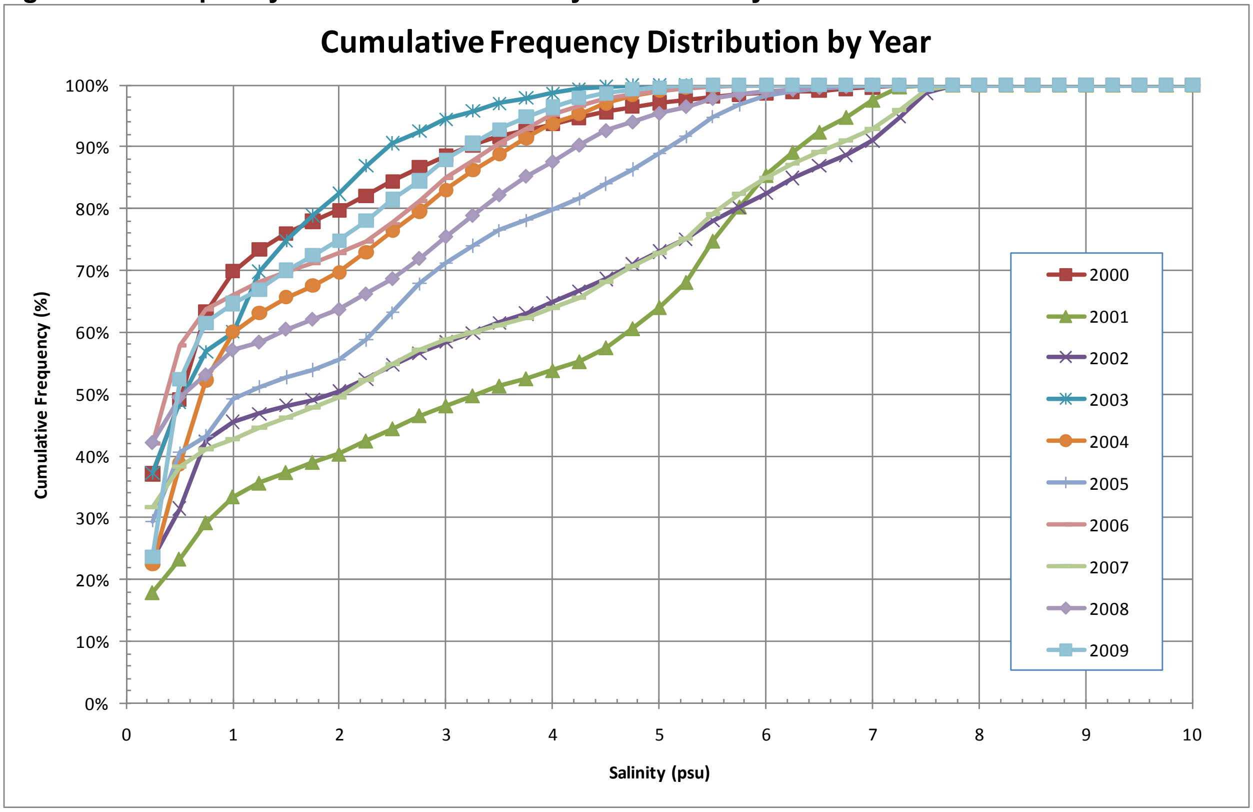


Figure 5-4. Cumulative frequency distributions for each year of the 10-yr record.

5.3 Monthly Analysis for Each Month in 10-yr Record

The statistical summary of the 10-yr data set broken down by month is shown in Table 5-4 and Figure 5-5. Counts for each month vary from 6,698 to 7,440, differing based on years that have fewer days and missing data. February has 672 hrs during non-leap years and 696 hrs during leap years. The data shows that the months of July through October have higher salinities while the other months have lower salinities, with April the lowest. Highest maximum salinities occur between July and December, with all exceeding 7.20 psu while the minimum salinities vary for all months between 0.07 and 0.11 psu. The mean is consistently larger than the median indicating that there are more lower values than higher values. The 90th percentile salinities show values greater than 6 psu during August, September, and October.

Table 5-4. Statistical summary for each month of the 10-yr record.

Month	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
Jan	7440	1.11	0.08	6.77	0.39	3.56
Feb	6792	1.59	0.11	6.96	1.09	3.65
Mar	7433	1.08	0.10	5.84	0.63	3.16
Apr	7100	0.52	0.08	4.51	0.13	1.83
May	7276	0.76	0.07	6.60	0.21	2.95
Jun	6698	1.22	0.10	6.07	0.35	3.33
Jul	6804	2.56	0.08	7.27	2.39	5.31
Aug	6739	3.22	0.09	7.55	3.05	6.46
Sep	6939	3.84	0.11	7.67	3.70	7.16
Oct	7422	3.13	0.11	7.66	2.78	6.46
Nov	7200	1.76	0.09	7.63	0.77	5.13
Dec	7349	1.04	0.09	7.26	0.28	3.83

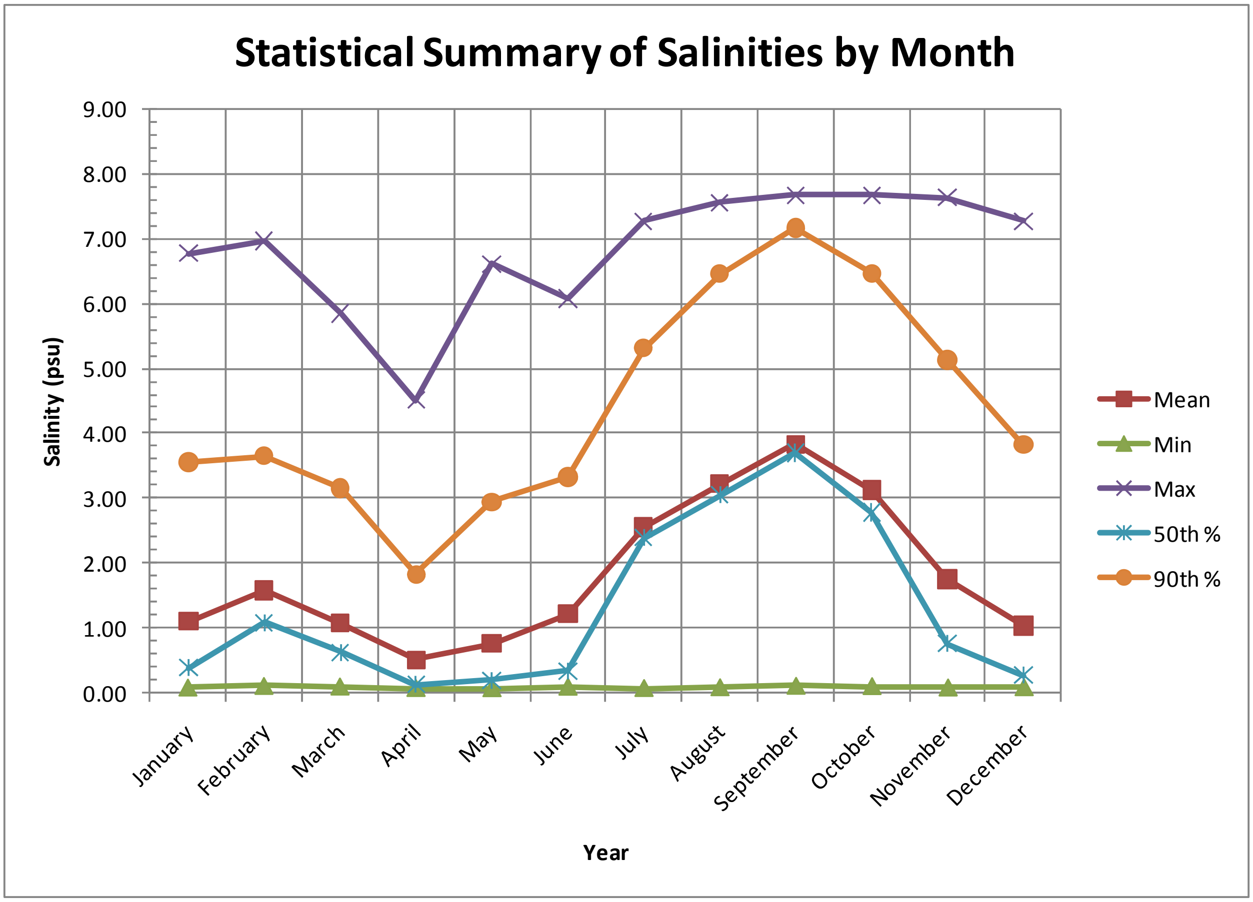


Figure 5-5. Statistical summary by month for the 10-yr period.

Figures 5-6 and 5-7 show the frequency distribution and cumulative frequency distribution, respectively for each month in the 10-yr record. Salinities between 0 and 0.25 psu vary between 5% of the time in September and 85% in April, consistent with freshwater discharge to the River. Generally, there is a dramatic drop for the salinity bin between 0.25 and 0.50 psu for most months. Above 1.5 psu, no salinity bins exceed a frequency greater than 5% except for September for the 7.5-psu bin. Cumulative frequency distributions indicate that between 18% (in September) and 86% (in April) of the salinities are less than 1.00 psu.

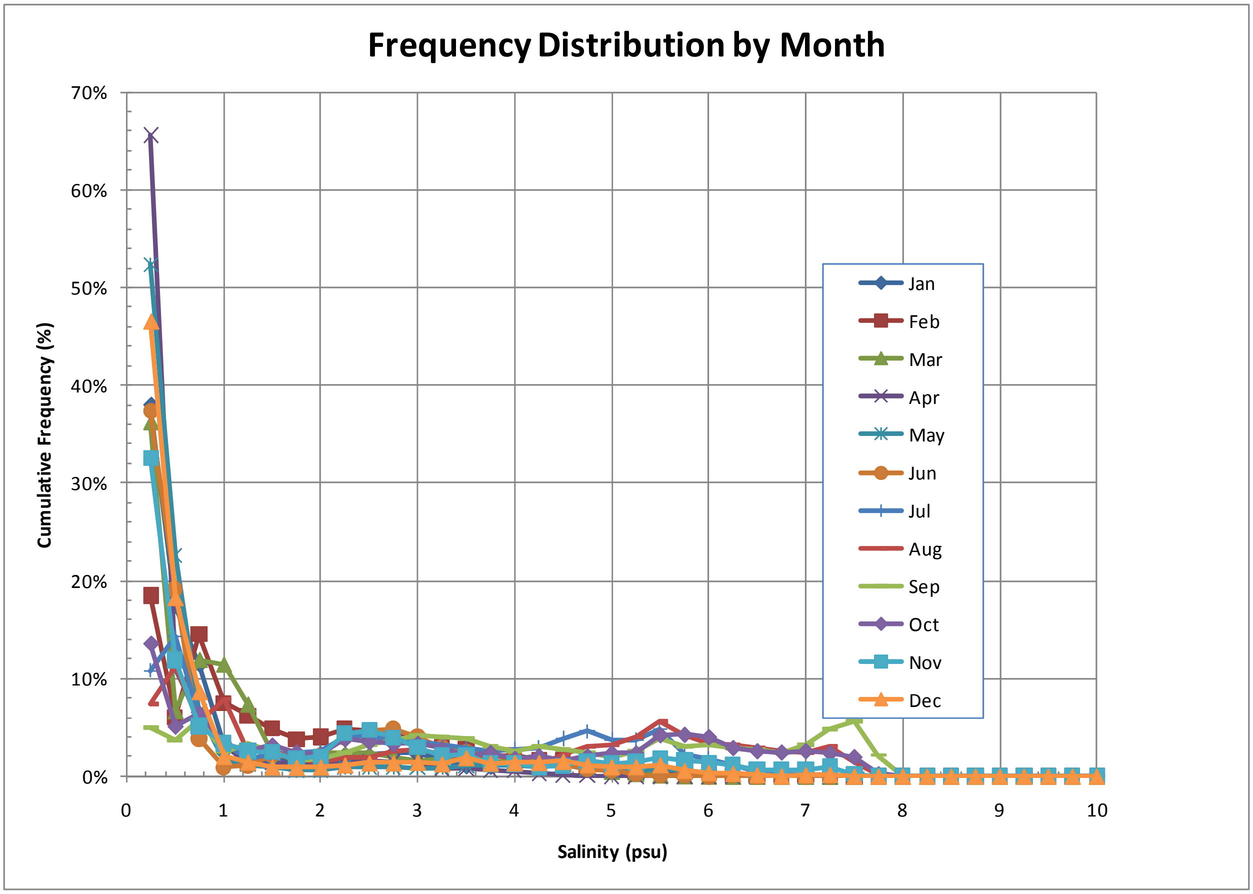


Figure 5-6. Frequency distributions for each month of the 10-yr record.

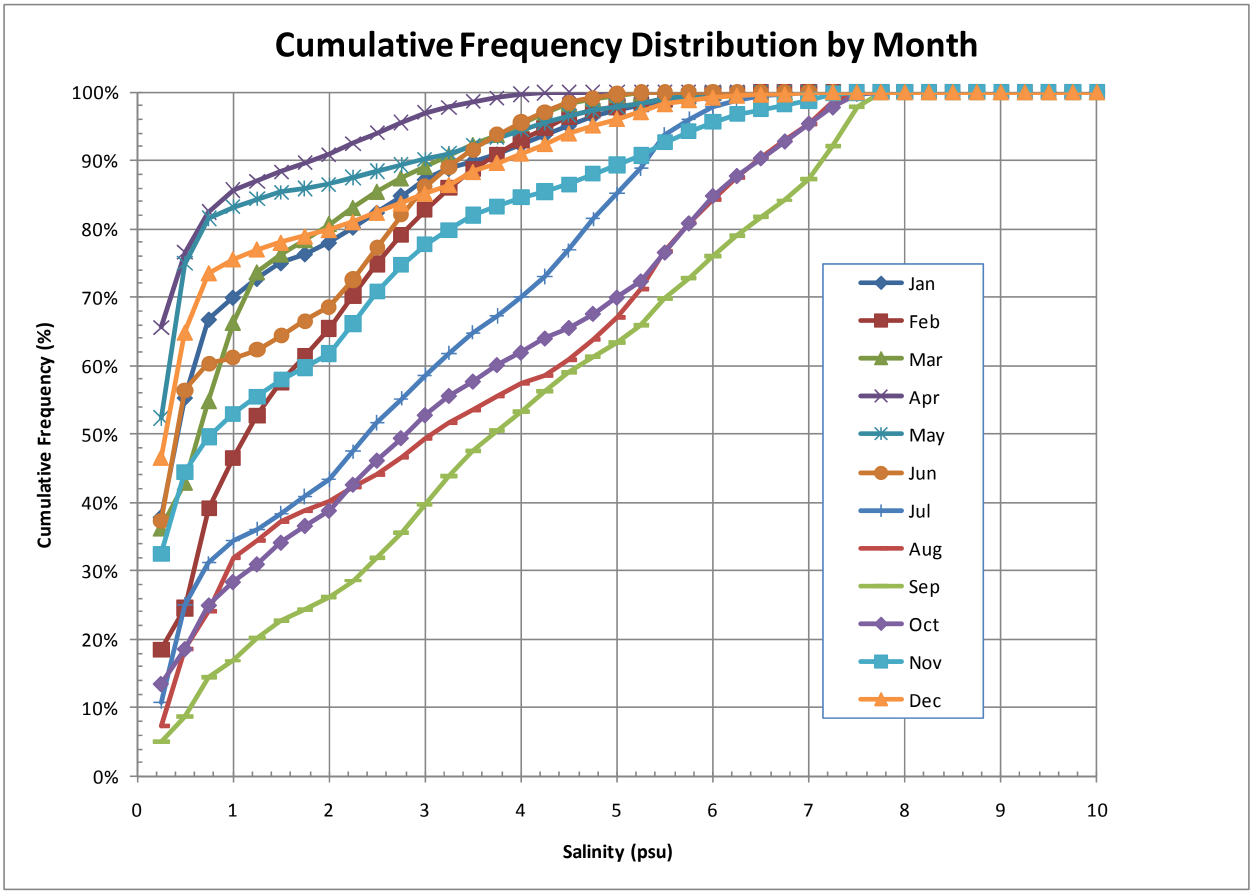


Figure 5-7. Cumulative frequency distributions for each month of the 10-yr record.

5.4 CONTINUOUS 10-YR DATA SET ANALYSIS

As noted in Section 5.1 there were a total of only 85,192 hrs of data in the 10-yr record of model predictions due to missing data values in the original USGS data records used. Since there are 87,672 hrs in the period 2000 through 2009 a total of 2,480 hrs were missing. In order to provide a continuous time series for subsequent analysis of cooling tower operation the missing values needed to be interpolated from the predictions. An analysis of the missing hours reveals that the largest gap extended for 739 hrs down to 60 1-hr gaps summarized in Table 5-5.

Table 5-5. Summary of data gaps in the 10-yr record.

Start Time	Gap Duration (hr)
8/3/03 15:00	739
6/9/04 23:00	324
6/10/03 10:00	167
7/4/08 0:00	154
7/1/05 19:00	88
4/15/05 8:00	78

Start Time	Gap Duration (hr)
9/20/05 5:00	53
5/28/02 14:00	44
7/23/06 1:00	41
7/27/06 4:00	41
12/17/00 23:00	35
7/17/06 21:00	24
7/22/06 0:00	24
7/25/06 3:00	24
7/19/06 23:00	23
7/26/06 4:00	23
7/21/06 1:00	22
7/16/06 20:00	14
7/18/06 22:00	13
7/16/06 7:00	12
12/15/00 21:00	11
4/14/05 19:00	11
12/14/00 22:00	9
8/1/05 14:00	9
7/15/06 20:00	9
7/17/06 11:00	9
9/6/02 21:00	8
9/24/07 20:00	8
Number of Gaps	
12	7
20	6
17	5
6	4
12	3
27	2
60	1

Since the total number of missing values is only 2.8% of the total hrs in 10 yrs the form of the interpolation would not likely affect overall distribution of salinity values. Therefore a simple linear interpolation was used to estimate the missing values. To check whether the interpolation affected the distribution, the statistical analyses used in previous sections was repeated. The statistical summary for the continuous entire 10-yr record is given in Table 5-6. The only differences from the results in Table 5-1 are a 0.01 psu increase in mean and 50th percentile values and a 0.01 psu drop in 90th percentile value, none of which are significant.

Table 5-6. Statistical summary for the continuous entire 10-yr record.

Period	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
2000-2009	87672	1.81	0.07	7.67	0.73	5.22

The statistical summary for each year of the continuous 10-yr record is shown in Table 5-7. The differences of the means compared to Table 5-3 vary from 0 psu in 2001 and 2008 up to a maximum of 0.10 psu in 2003. The largest difference in 2003 is due to the relatively large number of missing hours, greater than 900 hrs. The largest difference in the 50th percentile was also 0.10 psu and the largest difference in the 90th percentile was 0.18 psu, all occurring during 2003.

Table 5-7. Statistical summary for each year of the continuous 10-yr record.

Period	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
2000	8784	1.11	0.10	7.63	0.52	3.19
2001	8760	3.21	0.09	7.40	3.28	6.32
2002	8760	2.79	0.09	7.67	2.01	6.97
2003	8760	1.07	0.10	5.08	0.62	2.64
2004	8784	1.34	0.11	5.84	0.68	3.58
2005	8760	1.95	0.10	7.13	1.09	5.12
2006	8760	1.12	0.08	6.23	0.36	3.41
2007	8760	2.74	0.08	7.67	2.08	6.67
2008	8784	1.56	0.07	7.23	0.56	4.19
2009	8760	1.16	0.11	5.76	0.45	3.20

The statistical summary for each month of the continuous 10-yr record is shown in Table 5-8. The difference in the means compared to Table 5-4 vary from 0.00 psu for January, February, March and November up to a maximum of 0.11 psu for July, consistent with the most months with missing data summarized in Table 5-5. The largest difference for the 50th and 90th percentiles occurred in August, consistent with the largest gap in August.

Table 5-8. Statistical summary for each month of the continuous 10-yr record.

Month	Count (hrs)	Mean (psu)	Minimum (psu)	Maximum (psu)	50th Percentile (psu)	90th Percentile (psu)
Jan	7440	1.11	0.08	6.77	0.39	3.56
Feb	6792	1.59	0.11	6.96	1.09	3.65
Mar	7440	1.08	0.10	5.84	0.63	3.15
Apr	7200	0.51	0.08	4.51	0.13	1.80
May	7440	0.75	0.07	6.60	0.19	2.90
Jun	7200	1.17	0.10	6.07	0.35	3.26
Jul	7440	2.45	0.08	7.27	2.30	5.26
Aug	7440	3.14	0.09	7.55	2.76	6.37
Sep	7200	3.90	0.11	7.67	3.77	7.22
Oct	7440	3.14	0.11	7.66	2.79	6.49
Nov	7200	1.76	0.09	7.63	0.77	5.13
Dec	7440	1.06	0.09	7.26	0.29	3.81

6 CONCLUSIONS

An analysis was performed to estimate the variability of salinity at the intakes to IPEC on the River. Long-term (greater than a decade) data records of conductivity were identified for active USGS stations at West Point and Hastings that are located 9 mi upstream and 21 mi downstream of IPEC, respectively. In addition, a discontinued USGS station at Tomkins Cove, located 1 mi south of IPEC, was identified that had a shorter (4-yr) period of record. Since the Tomkins, station was relatively close to IPEC it was used as a proxy for salinity at the IPEC intakes.

A statistical analysis was performed on the hourly salinity data for each period of record for each station. Statistics, including mean, minimum, maximum, 50th and 90th percentile values, along with frequency and cumulative frequency distributions, were calculated. The analysis revealed a decrease in salinity from Hastings to Tomkins and from Tomkins to West Point, consistent with their locations moving upriver. Mean salinity at Hastings was 6.29 psu, Tomkins was 2.09 psu, and West Point was 0.79 psu, consistent with the order of the 90th percentile salinity values of 10.88 psu (Hastings), 4.96 psu (Tomkins) and 2.63 psu (West Point). Hastings and West Point showed the lowest mean and 90th percentile values in April, consistent with high freshwater discharge, and highest mean and 90th percentile values in September, consistent with low freshwater discharge. Tomkins, with a significantly shorter period of record, showed the lowest mean and 90th percentile values in January and the highest in August.

A correlation analysis was performed that related the salinity at Tomkins to salinities at West Point and Hastings. It was found that the West Point data was more highly correlated to Tomkins than Hastings was and thus used to estimate Tomkins salinity for the long-term decadal period. The model was improved at low salinities by forcing the Tomkins salinity to be equal to the West Point salinity when the Hastings salinity fell below 4.07 psu. This improvement had no effect on higher salinity predictions.

The decadal (2000-2009) salinity time series at IPEC (assumed equivalent to that at Tomkins) was generated to provide a long-term estimate of salinity under a variety of environmental conditions. This time series is consistent with the analysis period conducted for the extreme environmental conditions in support of the hydrothermal modeling at IPEC (Swanson et al., 2010).

The model results showed that salinities were typically higher in the summer and fall seasons, consistent with the observations at the USGS stations. Some years (2000, 2001, and 2006) showed extended periods of salinity exceeding 5 psu for three months with peaks exceeding 7 psu. There were also shorter periods when the salinity was near-zero (2000, 2001, and 2008), usually in the spring season. These variations are primarily due to fluctuations in freshwater entering the River, although there are occasional events (storm surge) that can transport salt from the ocean to the vicinity of the IPEC intake.

A statistical analysis was performed on the hourly-modeled salinity predictions at IPEC for the decadal period 2000 through 2009. The mean salinity over the entire period was 1.80 psu, the minimum 0.07 psu and the maximum 7.67 psu. The median, or 50th percentile, was 0.72 psu, indicating that the salinity distribution is not a normal distribution, but slightly biased to lower salinities. The 90th percentile salinity was 5.23 psu. Salinities between 0 and 0.25 psu were found to occur 30.62% of the time while salinities between 0.25 and 0.50 psu dropped to 12.29% of the time. The large number of low salinities is indicated by the cumulative frequency of occurrence that shows over 50% (54.78%) of the salinities were less than 1.00 psu.

The statistical summary of the 10-yr data set broken down by year showed that 2001 had the highest mean (3.21 psu) and highest median (3.28 psu), 2002 had the highest maximum (7.67 psu) and highest 90th percentile (6.90 psu). Salinities between 0 and 0.25 psu occurred between 12% of the time in 2000 and 42% in 2009 while salinities between 0.25 and 0.50 psu dropped dramatically for all years. The large number of low salinities was indicated by the cumulative frequency of occurrence that showed between 33% (in 2001) and 70% (in 2000) of the salinities are less than 1.00 psu.

The statistical summary of the 10-yr data set broken down by month showed that September had the highest mean (3.84 psu), highest maximum (7.67 psu), highest median (3.70 psu) and highest 90th percentile (7.16 psu). July, August, October and November had the next highest values after September. The winter and spring months had lower values with April the lowest of any month. Salinities between 0 and 0.25 psu varied throughout the year, with such low values occurring only 5% of the time in September and as high as 85% in April, directly related to the freshwater discharge to the River while salinities between 0.25 and 0.50 psu dropped dramatically for most months, excepting those with lowest salinities. The large number of low salinities is indicated by the cumulative frequency of occurrence that shows between 18% (in September) and 86% (in April) of the salinities are less than 1.00 psu.

The effect of using linear interpolation to fill the missing hours (2.8% of the total hours) is insignificant when viewed in the context of the 10-yr record as all statistical measures showed a maximum difference of only 0.01 psu when compared to the results of the non-filled data set. The individual years and months exhibited larger differences but were still relatively small.

7 References

Swanson, C., D. Mendelsohn, Yong Kim, and D. Crowley, 2010. Hydrothermal Modeling of the Cooling Water Discharge from the Indian Point Energy Center to the Hudson River. ASA Project 09-167. Prepared for Elise Zoli, Goodwin Procter, Boston, MA, 22 March 2010.

Texas Instruments, 1976. A synthesis of available data pertaining to major physicochemical variables within the Hudson River Estuary emphasizing the period from 1972 to 1975. Prepared by Texas Instruments Incorporated Ecological Services, Dallas, TX. Prepared for Consolidated Edison Company of New York, Inc., New York, NY, November 1976.