IPRenewal NPEmails

From:	Gray, Dara F <DGray@entergy.com>
Sent:	Wednesday, September 14, 2016 3:10 PM
To:	Wentzel, Michael
Cc:	Louie, Richard
Subject:	[External_Sender] RE: Submitted Comments
Attachments:	Attachment C.pdf.pdf; Attachment D.PDF; D=NOAA-NMFS-2015-0107-0001&p.pdf

And here is the rest of the attachments

Dara Gray REM
Chemistry/Environmental
Indian Point Energy Center
Dgray@entergy.com
914-254-8414

From: Gray, Dara F
Sent: Wednesday, September 14, 2016 2:59 PM
To: 'WENTZEL, MICHAEL J'
Cc: Louie, Richard
Subject: Submitted Comments

Mike
As discussed, attached are the comments submitted on behalf of Entergy regarding NMFS proposed critical habitat listing for the HR in this area. If this zip file does not go through, it will likely take a few emails due to attachment file size.
Please let me know if you have any questions.

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Hearing Identifier: IndianPointUnits2and3NonPublic_EX
Email Number: 7989

Mail Envelope Properties (DA94DFACF1201C4A91A21BD336C2520A35E85C52)

Subject: [External_Sender] RE: Submitted Comments
Sent Date: 9/14/2016 3:09:51 PM
Received Date: 9/14/2016 3:10:32 PM
From: Gray, Dara F

Created By: DGray@entergy.com

Recipients:
"Louie, Richard" <rlouie@entergy.com>
Tracking Status: None
"Wentzel, Michael" <Michael.Wentzel@nrc.gov>
Tracking Status: None

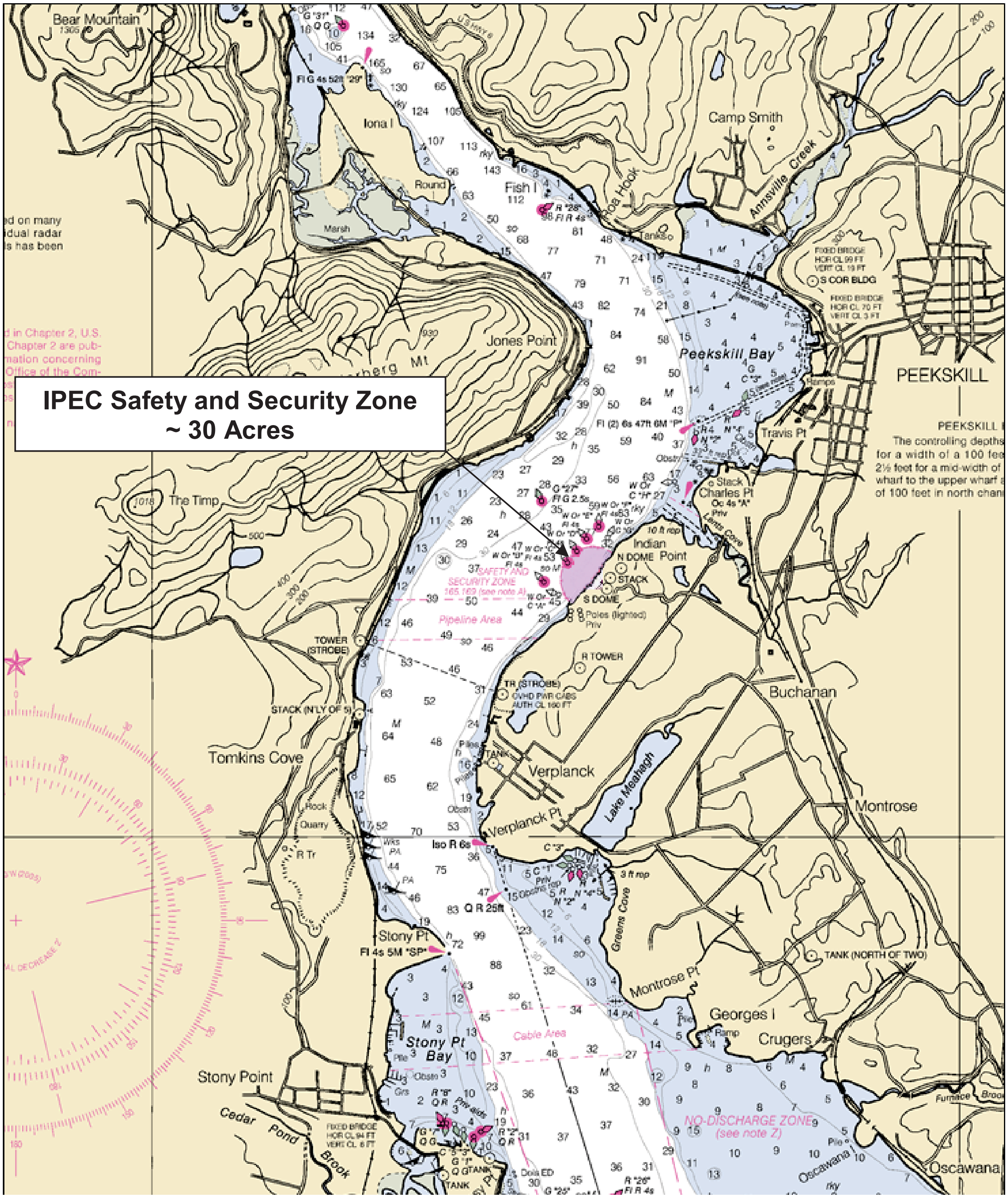
Post Office: LITXMETSP003.etrsouth.corp.entergy.com

Files	Size	Date & Time
MESSAGE	767	9/14/2016 3:10:32 PM
Attachment C.pdf.pdf	769912	
Attachment D.PDF	1923114	
D=NOAA-NMFS-2015-0107-0001&p.pdf	136220	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

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.

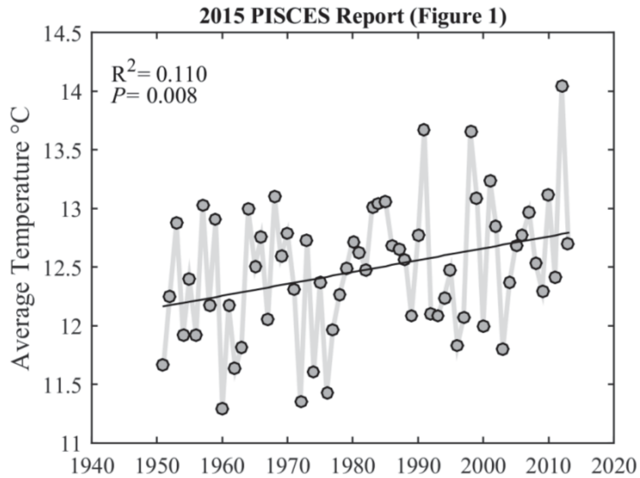


Figure 1. **Reproduced from the PISCES Report (Henderson and Seaby 2015) using digitized data from Appendix B-6 of the 2013 Year Class Report which corroborates their results in their Figure 1, but unlike their figure, the low R^2 reported here indicates that only 11% of the variation in annual temperature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

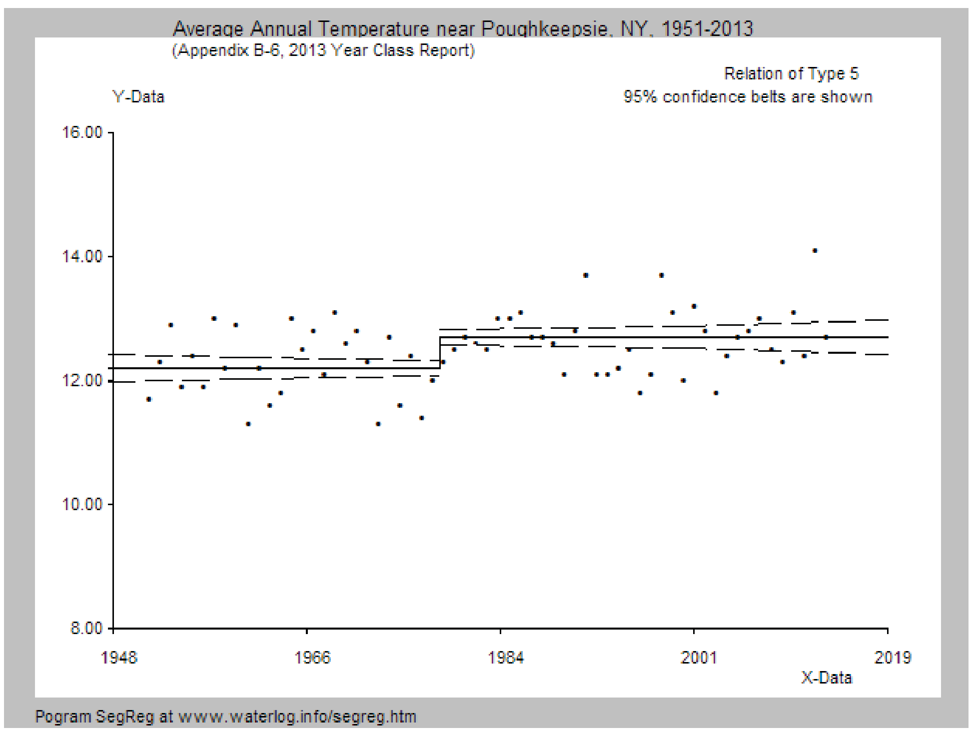


Figure 2. **1951 through 2013 annual mean water temperature from Appendix B-6 of the 2013 Year Class Report used in the PISCES Report (Henderson and Seaby 2015) consisted of a significant break point separating the time series into two periods (1951-1978 and 1979-2013) each with no trends (i.e., no significant 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: Beach Seine Stations (Task 23)		Ichthyoplankton (not standardized) (Task 88)		Fixed Water Quality Stations (Task 89)		Fall Juvenile (not standardized) (Task 98)		Total	
	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**	**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 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	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	163	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	154	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	183	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	183	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	183	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	183	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	183	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		183		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

NORMANDEAU environmental consultants

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

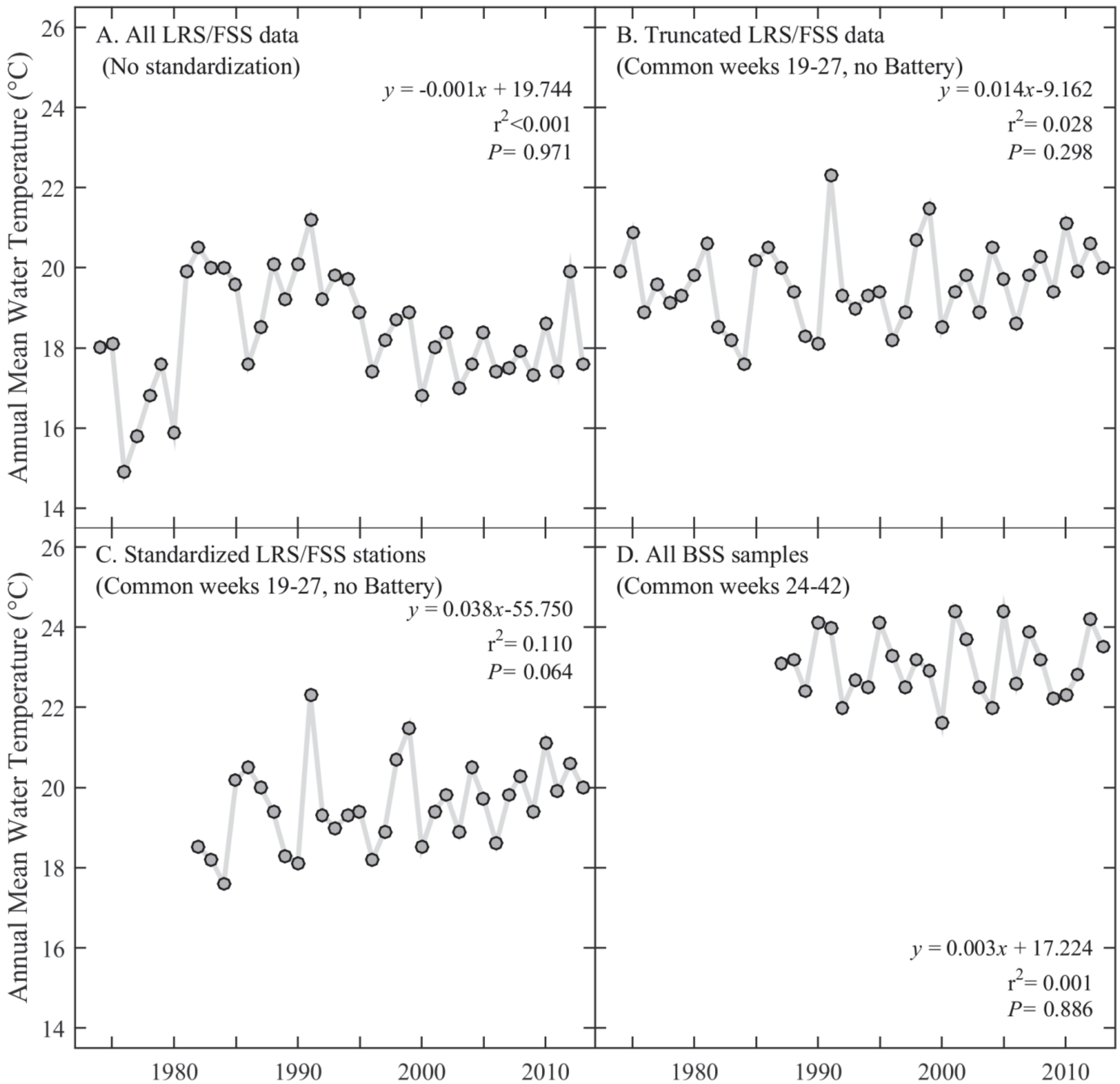


Figure 3. Annual Mean Water Temperature in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except truncated for 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.

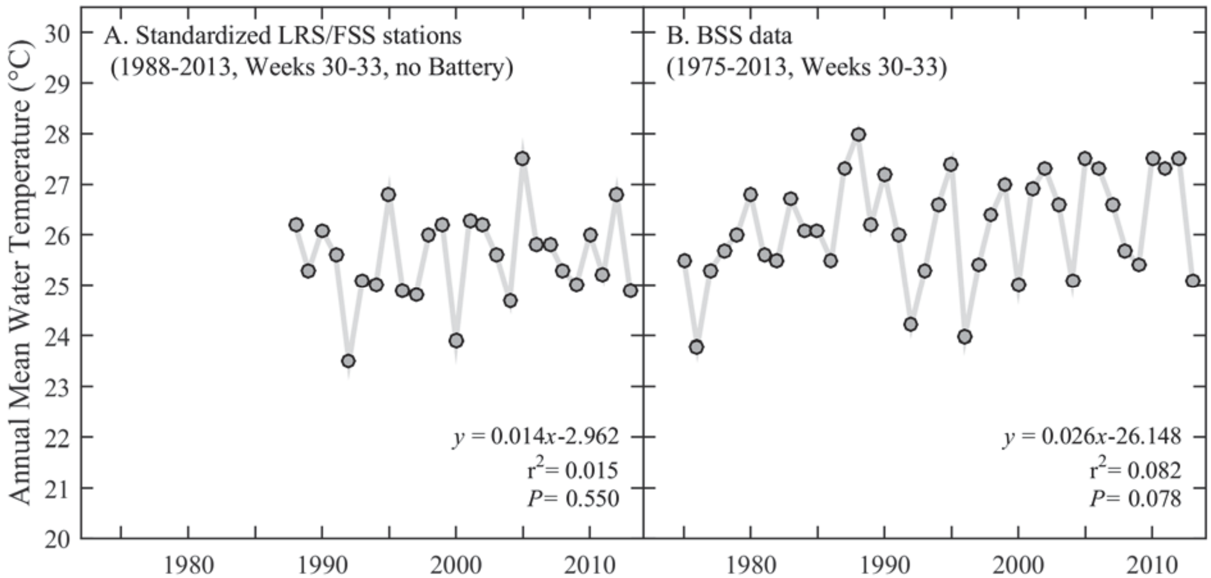


Figure 4. **Annual Mean Water Temperature for the Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among all regions 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.**

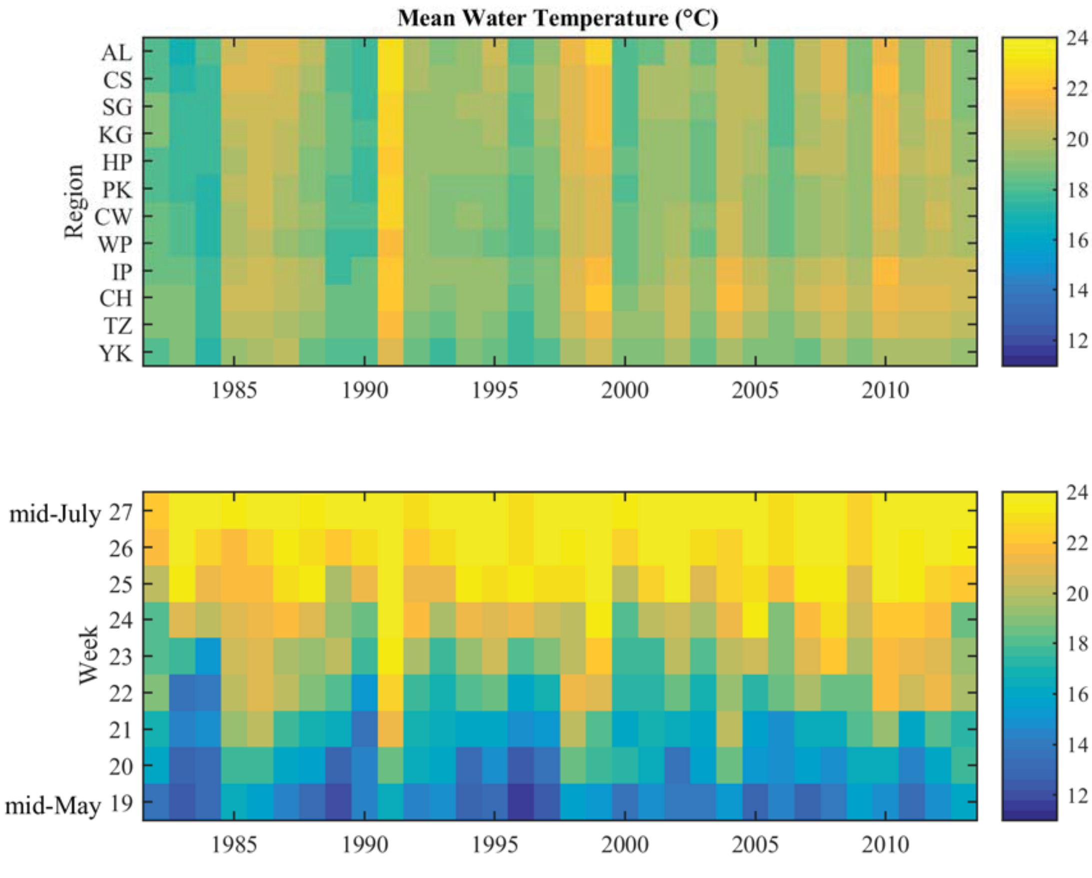


Figure 5. Image plots illustrating the variation in water temperature by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

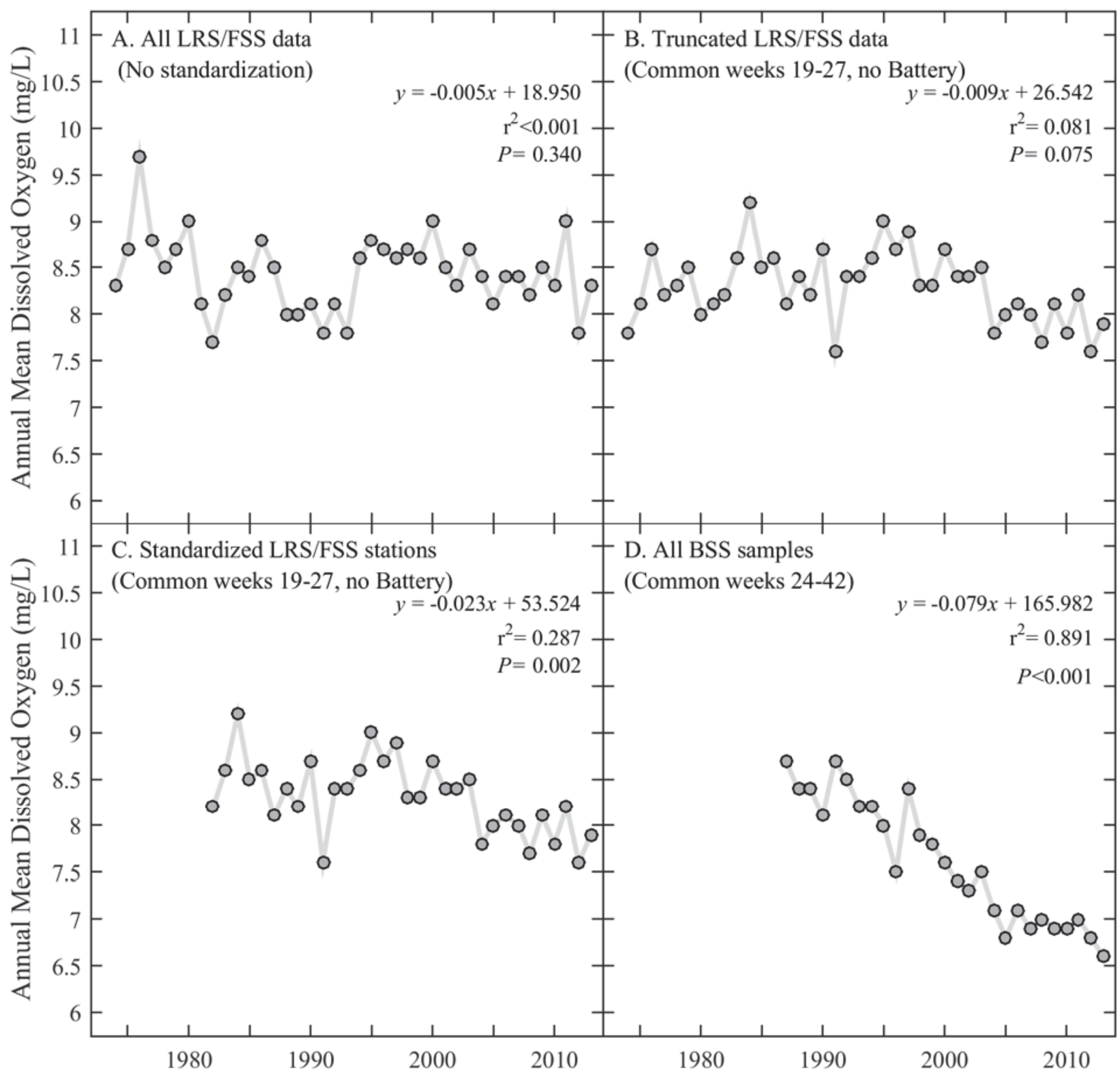


Figure 6. **Annual Mean Dissolved Oxygen in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except truncated for 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.

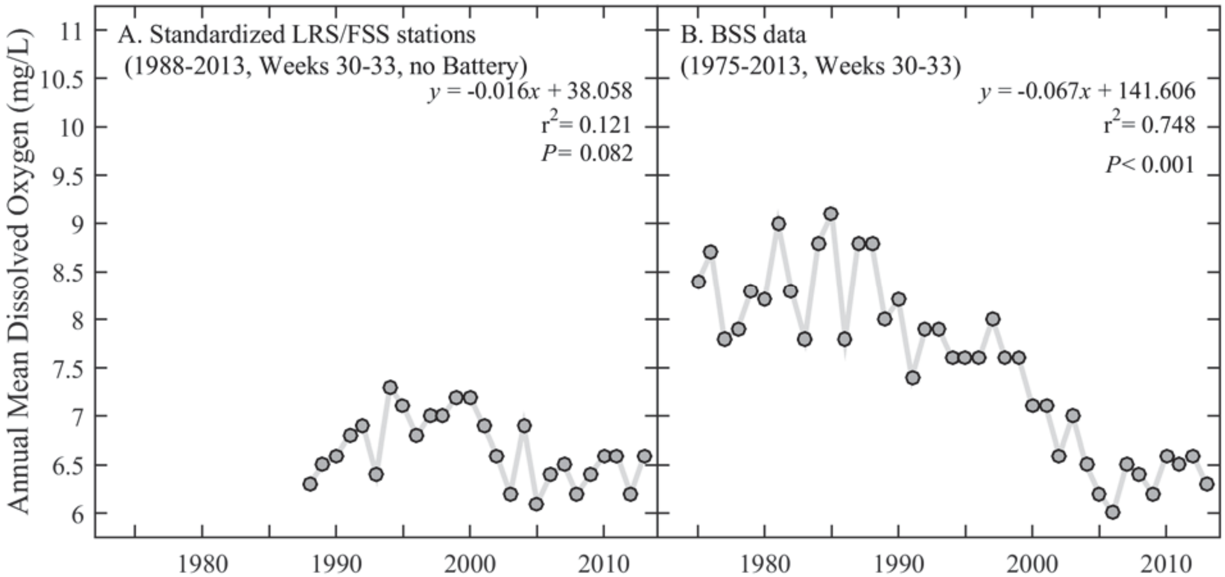


Figure 7. Annual Mean Dissolved Oxygen Concentration for the Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among 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.

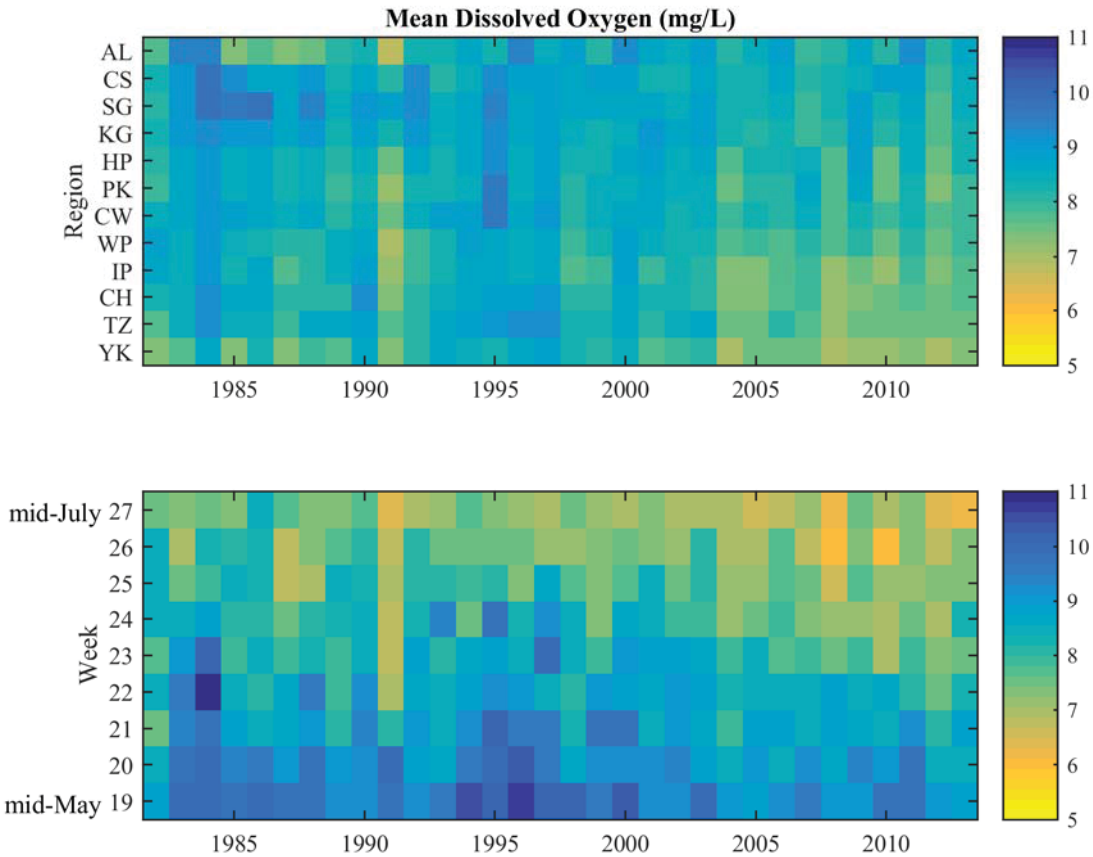


Figure 8. Image plots illustrating the variation in dissolved oxygen concentration by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

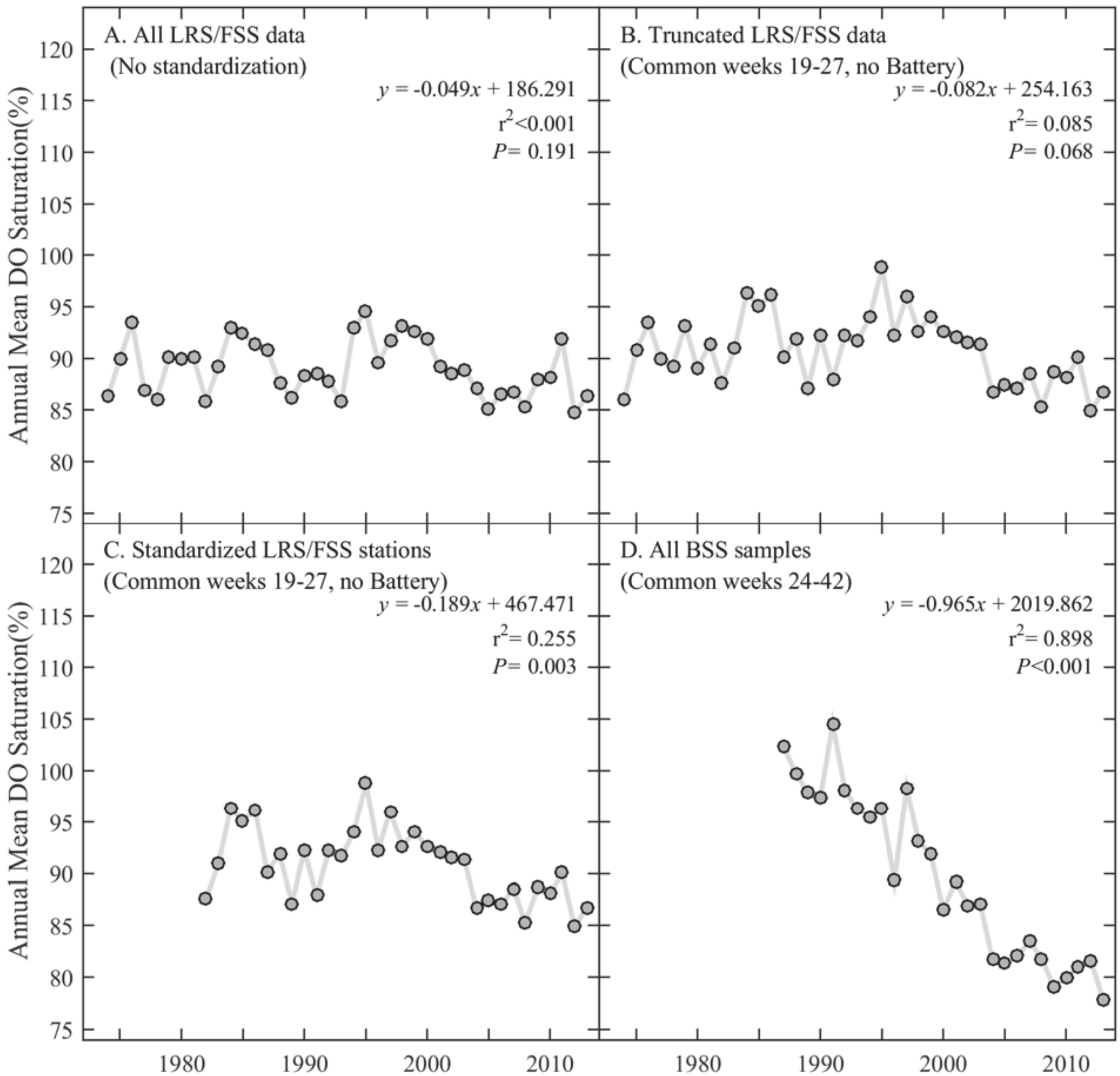


Figure 9. **Annual Mean Dissolved Oxygen (DO) Saturation in the Hudson River Estuary from 1974 through 2013. A) All measurements (Task Code = 88,89, and 98) from Long River Survey (LRS) and Fall Shoals Survey (FSS) without regard to spatial or temporal differences in sample design; B) same as (A) except 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.

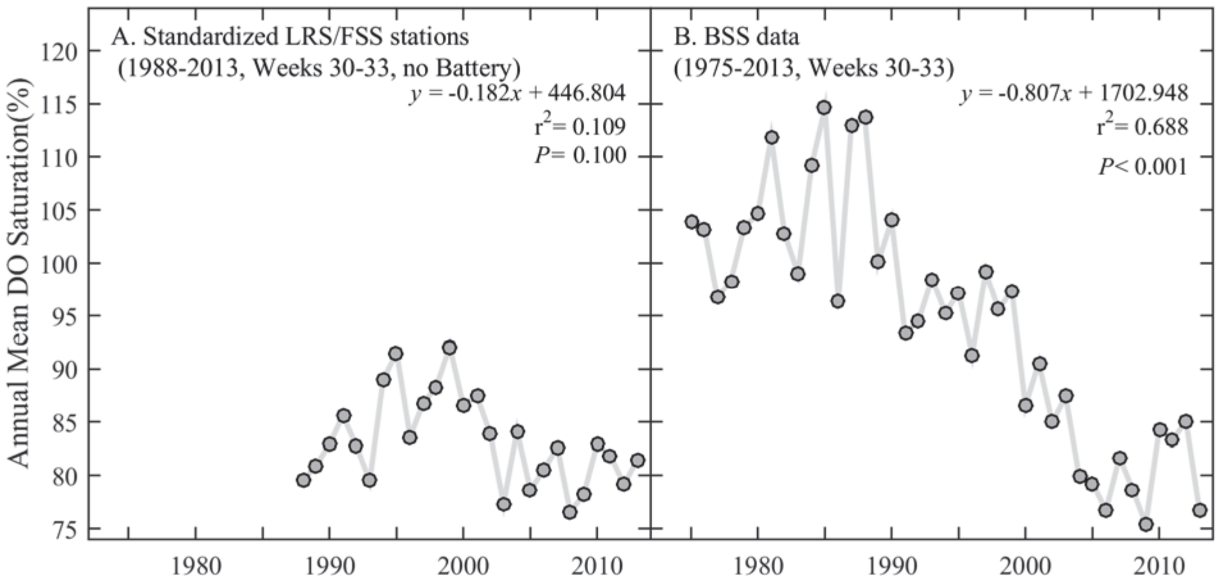


Figure 10. Annual Mean Dissolved Oxygen Saturation for Warmest Month (Weeks 30-33) in the Hudson River Estuary from 1974 through 2013. A) Long River Survey (LRS) and Fall Shoals Survey (FSS) (Task Code = 89 only) sampled at the fixed sampling water quality stations; and B) Beach Seine Survey among all 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.

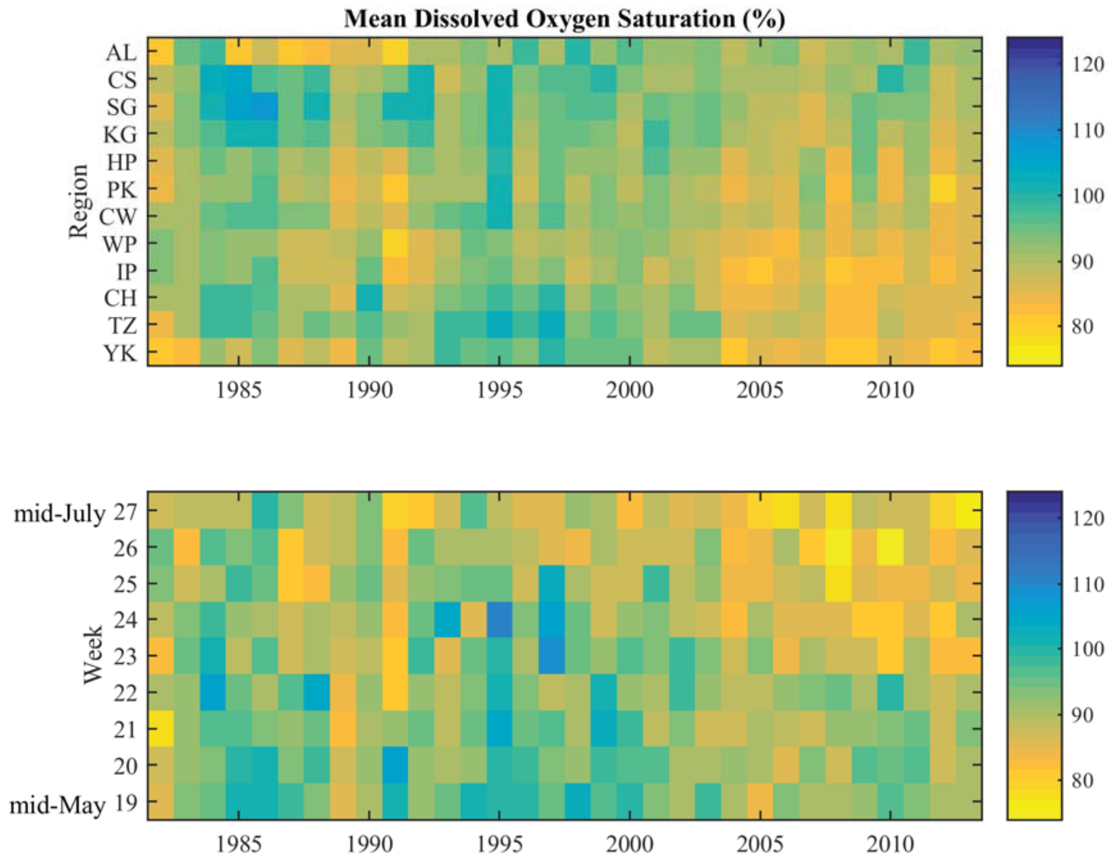


Figure 11. Image plots illustrating the variation in dissolved oxygen saturation by region (top) and week (bottom) in the Hudson River from 1982 through 2013 based on a standardized subset of LRS/FSS data (Data set #3).

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