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Incidence and Timing of Low Dissolved Oxygen Events in the Squamscott River: 2005-07

Stephen H. Jones
University of New Hampshire - Main Campus, Stephen.Jones@unh.edu

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A Final Report to
The New Hampshire Estuarine Project

Addendum to:
"Impacts of Wastewater Treatment Facilities on Receiving Water Quality"

Submitted by

Steve Jones
Jackson Estuarine Laboratory
University of New Hampshire
Durham, NH 03824

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EXECUTIVE SUMMARY

The Squamscott River has had extended episodes of low dissolved oxygen (DO) that have been recorded at a site near its mouth during the past few years. These episodes were recorded as a result of temporally intensive monitoring by a datasonde deployed through most of each year. Whereas low DO events can occur during April-November, events during the colder months are typically less frequent and are often caused by unusual natural or severe weather conditions. Low DO events occur most frequently during July-September when elevated levels of nutrients are most likely to contribute to their cause, and are thus of most concern.

The study found the warm season time period of July-September to be the time of year when low DO events were most frequent and pervasive. In comparisons between each year from 2005 to 2007, 2005 had less frequent and pervasive low DO events compared to 2006 and 2007. Relative to tidal cycle conditions, low DO conditions were most likely to occur during neap tide conditions, as indicated by the least shallow depth readings for the data sonde. Beyond the seasonal and tidal time periods, the time of day where conditions are most likely to cause low DO events is also critical for focusing field efforts. The most frequently observed time of day when either a low DO event was initiated or the lowest DO reading was recorded was in the morning, especially before 8:00 AM. Much less frequent occurrence of these events was observed during the second half of days.

It appears that the predicted conditions for conducting water measurements and sampling during 2005 were relatively accurate. The study should have been more successful except that 2005 was a year in which low DO episodes were less frequent and pervasive. Future studies in the Squamscott River area near the data sonde can benefit from use of the results reported herein. The same kind of analysis could also be used to help inform studies in other areas of the estuary where data sondes are nearby and have available databases for water quality conditions.

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INTRODUCTION

Contaminants of concern discharged to tidal waters in effluent from wastewater treatment facilities (WWTFs) are controlled through the permitting process for every facility in New Hampshire. Several types of effluent characteristics are universally controlled, including solids, coliform bacteria, ammonia and biological oxygen demand (BOD). However, no Seacoast NH facility is yet permitted for nutrients like nitrogen and phosphorus. The impact of effluent on the oxygen in the receiving water is mitigated by removal of BOD, but high loading of nutrients can have a detrimental impact through the process of eutrophication. High loading rates of nutrients, especially nitrogen in estuarine waters because it is typically limiting, can stimulate the growth of phytoplankton and nuisance algae. Over production of plants eventually causes die off and the decomposition of algal biomass by heterotrophic bacteria is an oxygen-demanding process. Too much demand on dissolved oxygen (DO) in the water, especially in warmer months can cause episodic or chronic periods of hypoxia, and even anoxia. Other processes also can be oxygen demanding. Ammonium in effluent can also cause oxygen demand because it is oxidized to nitrate by nitrifying bacteria in receiving waters, and even low concentrations of BOD can have impacts under the right conditions.

The Squamscott River (NHEST600030806-01) was listed as "Not Supporting" for Aquatic Life Use Support because of low dissolved oxygen in the 2004 §305(b) report. It was de-listed for % saturation in the 2006 NH 305(b) report (http://www.des.state.nh.us/wmb/swqa/303dList.html), but remains listed for DO concentration (ppm). The Great Bay Estuarine Research Reserve has deployed oxygen sensors at the Squamscott River railroad bridge and at 4 other sites in the Great Bay Estuary in recent years. Data every 15-30 minutes has been radioed back to Jackson Estuarine Laboratory from these sites, providing an intensive real-time picture of conditions. Episodes of depressed (<5.0 mg/l & < 75% saturation) DO occurred at the one site in the Squamscott River during 2003 and 2004. The New Hampshire National Coastal Assessment (NCA) also documented depressed oxygen at several Squamscott River sites at both ends of the river in 2000- 2004. The NCA program also conducted two synoptic assessments at 15 sites in the river in 2004 to provide a better sense of the geographical range of these episodes (Jones 2005).

The low DO episodes in the Squamscott River were recorded as a result of temporally intensive monitoring by a datasonde deployed from April to December. Whereas low DO events can occur throughout this time period, events during the colder months are often caused by unusual natural or severe weather conditions. In contrast, low DO episodes occur most frequently during July-September when elevated levels of nutrients are most likely to contribute to their cause, and are thus of most concern. As part of a larger study to discern the wider spatial extent and causes of low DO events in the Squamscott River (Jones 2007), there was a need to predict when these events were most likely to occur to enable planning and field deployment of resources. Sampling and measurements were taken on five dates in 2005 and one in 2006. Only one date, August 19, 2005, showed

spatially extensive low DO levels. Results on the other sample dates showed either acceptable levels, or low DO levels were confined only to small areas on two other dates. The areas where low DO levels occurred on the three dates were all distinctly different areas of the river, possibly reflecting different causes, tidal transport of low DO waters, or as some factor of sample timing relative to conducive conditions. Overall, conditions recorded by the datasonde for 2005 showed greatly diminished episodes of depressed DO levels compared to previous years.

STUDY GOALS

The goal of this study was to provide information that would help predict when conditions for low DO are most likely to occur. Data from the Squamscott River datasonde were analyzed to determine when low DO episodes occurred during 2005-07. The main questions being addressed were whether criteria chosen for the timing of field efforts conducted by Jones (2007) were accurate, and whether 2005 was an unusual year compared to previous and ensuing years relative to overall conditions conducive to the onset and incidence of low DO episodes.

METHODS

The method used to evaluate the timing of low DO events was to review existing data recorded at the Squamscott River data sonde from 2005 to 2007. Data from 2003-04 had been previously analyzed to help in predicting when to conduct field assessments of the spatial extent of low DO episodes on the river as part of a larger project that included this study (Jones 2007).

Data from all sondes deployed through the Great Bay National Estuarine Research Reserve System Wide Monitoring Program can be downloaded from the website for the National Estuarine Research Reserve System Centralized Data Management Office at http://cdmo.baruch.sc.edu/. The data used included date, time, DO % saturation, DO concentration and height of the data sonde as an indication of tidal amplitude and the effect of tidal cycles. Each time at which low DO was first recorded was considered the time of initiation of a low DO event. These events could occur as single recorded incidences or they could continue for longer time periods, so there could be more than one event in a day. Event duration was considered to be instantaneous for events with a single recorded incidence of low DO, as noted in the summary data tables in the following sections. The data were analyzed for seasonal, monthly and daily trends and characteristic conditions.

Data from the 2003 and 2004 sonde databases were also analyzed. Some of the key analyses have been summarized in Trowbridge (2006) and not included in this report.

RESULTS AND DISCUSSION

The DO % saturation and concentration data from 2003 to 2007 were analyzed to determine mean monthly values and to identify minimum and maximum values for each month (Table 1). DO measurements were made starting in April and continuing through December each month. The frequency of DO measurement by the sonde was every 30 minutes for 2003-06, and changed to every 15 minutes for 2007, thus doubling the number of data records for each month.

	Record	#	% DO saturation				DO concentration (mg/L)				First & last
2007	inverval	Records	mean	stdev	min	max	mean	stdev	min	max	days
Apr	0:15	2352	100.3	5.94	71.4	124.6	11.63	1.3	5.9	14.1	4/6/07
May	0:15	2976	95.9	4.69	80.5	107.5	9.17	0.77	7.3	10.9	
June	0:15	2880	91.1	10.47	71.3	134.5	7.7	0.68	5.9	11.2	
July	0:15	2976	98.2	13.69	49.7	146.4	7.41	0.9	4.1	11.2	
Aug	0:15	2976	103.7	13.05	52	134	7.6	0.94	4.1	9.9	
Sept	0:15	2880	99.6	13.84	58.3	135.3	7.75	1.04	4.8	10.5	
Oct	0:15	2976	93.9	12.56	65.4	134.3	8.08	0.89	5.6	10.6	
Nov	0:15	2880	90.9	3.62	82	105.8	9.98	0.76	8.3	11.8	
Dec	0:15	426	89.9	2.03	85.9	97.2	11.32	0.44	10	14.8	12/5/07
2006											
Apr	0:30	1070	103.0	10.22	81.9	132	10.53	1.26	7.9	13.6	4/6/06
May	0:30	1276	91.9	5.08	76.4	123.3	9.25	1.16	6.7	12.7	
June	0:30	1440	90.2	3.34	69.2	111.5	7.99	0.88	5.9	10.9	
July	0:30	1488	90.8	12.66	59.4	132.2	7.02	0.96	4.6	10.2	
Aug	0:30	1461	83.9	10.46	51.4	112.2	6.49	0.74	4	9	
Sept	0:30	1440	94.7	12.29	52.3	126.4	7.68	0.91	4.6	9.9	
Oct	0:30	1488	101.7	8.06	81.2	128.4	9.82	1.03	7.2	13	
Nov	0:30	1440	109.7	4.28	98.8	118.9	12.62	1.12	11	15.3	
Dec	0:30	215	114.6	1.78	110.5	119	13.38	0.58	12	14.8	12/5/06
2005											
Apr	0:30	1228	100.1	7.28	88.7	126	10.76	0.68	9.4	12.9	4/5/05
May	0:30	1487	106.3	5.55	92.7	122.5	10.84	0.74	9.6	13.2	
June	0:30	1440	89.9	17.93	61.7	153.4	7.7	1.58	5.5	13.9	
July	0:30	1488	113.6	19.49	77.2	168	8.73	1.31	5.7	12.3	
Aug	0:30	1488	107.8	14.59	55.3	141.2	7.98	1.08	4.5	10.7	
Sept	0:30	1440	107.2	22.26	59.7	150.5	8.14	1.52	4.8	11.4	
Oct	0:30	1488	87.2	15.27	48.5	119.1	8.72	1.81	5.4	12.5	
Nov	0:30	1438	97.3	10.61	48	113.9	11.41	1.93	5.3	15.4	
Dec	0:30	401	107.1	1.87	102.1	111.5	13.7	0.82	12	15.7	12/9/05
2004											
Apr	0:30	282	107.1	9.8	85	137.2	10.89	1.01	8.8	13.6	4/20/04
May	0:30	956	67.2	9.29	46.9	97.2	6.3	1.11	4	9.4	
June	0:30	1109	82.0	17.58	46.2	123.8	6.97	1.17	3.9	9.6	
July	0:30	1460	86.8	17.73	45.6	137.2	6.58	1.25	3.6	10.2	
Aug	0:30	1488	90.1	16.18	53.8	138.6	6.94	1.1	4.3	10	
Sept	0:30	1440	105.7	12.66	68.9	139.6	8.98	0.93	5.7	11.2	
Oct	0:30	1468	110.8	15.56	80.3	150.2	10.33	1.21	7.4	13	
Nov	0:30	1158	101.5	5.73	92.1	119.1	11.36	0.55	10	13.1	
Dec	0:30	649	101.6	2.93	93.7	109.3	13.08	1.18	11	15.7	12/14/04
2003											
Apr	0:30	352	105	4.76	96.2	115.1	11.05	0.4	9.8	12	4/23/03
May	0:30	1452	94.85	6.79	75.3	117	9.08	0.69	7.3	11.2	
June	0:30	1440	101.8	8.15	58	126.1	8.66	0.98	4.6	11	
July	0:30	1168	92.21	15.26	52.5	131.4	6.6	1.05	3.7	9.5	
Aug	0:30	1064	85.46	18.3	40	125.7	6.3	1.27	3	9.3	
Sept	0:30	0									
Oct	0:30	1075	84.22	6.46	57.1	96.9	8.17	0.81	5.5	9.9	
Nov	0:30	233	88.25	2.46	83	97	10.09	0.58	8.5	11.2	11/6/03

Table 1. Summary of % DO saturation and DO concentration data from the Squamscott River data sonde during 2005-2007.

The average % DO saturation values during 2005-07 were variable for most months (Figure 1). During the critical July-September period, the average monthly DO saturation was strikingly higher during 2005 compared to the other two years, especially 2006. The average DO concentrations during 2005-07 were relatively similar for most months, with the greatest variation during July and August, when the values for 2005 were again higher than for the other two years (Figure 2). As for % DO saturation, the lowest monthly average DO concentration occurred in August 2006. This suggests that 2005 was a year in which conditions conducive to low DO in the Squamscott River were not prevalent. Indeed, the frequency of days in which % DO saturation of DO concentration dipped below the state standards was lowest during 2005 compared to 2006 and 2007 (Table 2). The numbers of events and days in which DO concentration was lower than the state standard were fewer than for those for % DO saturation.

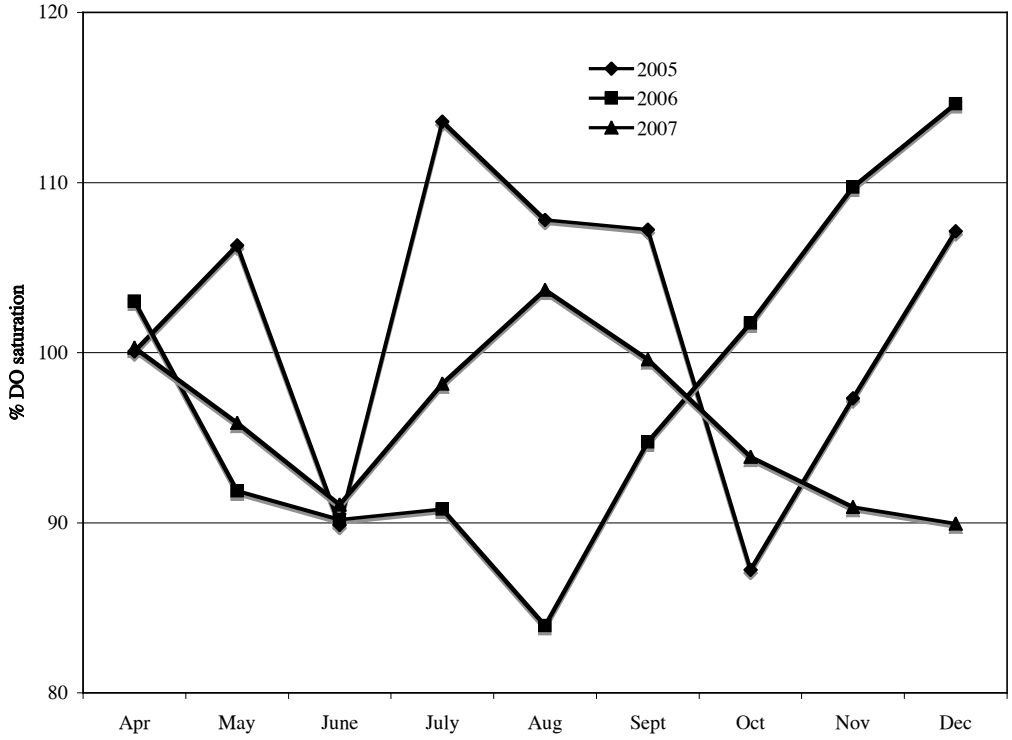


Figure 1. Monthly average % DO saturation values recorded by the Squamscott River data sonde: 2005-2007.

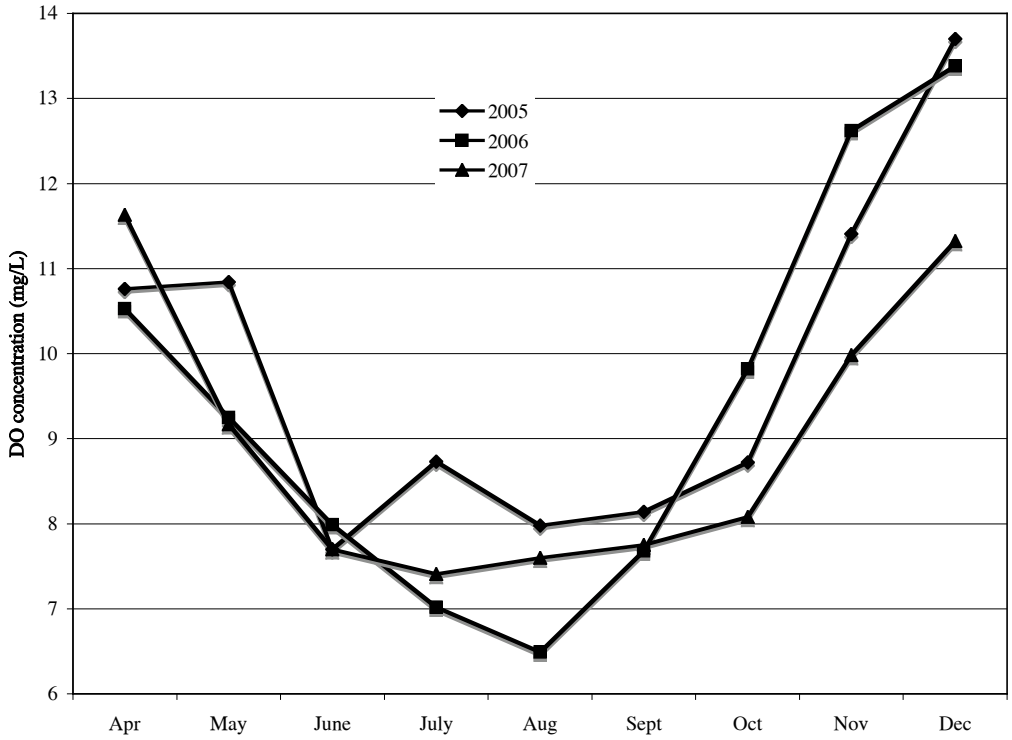


Figure 2. Monthly average DO concentration values recorded by the Squamscott River data sonde: 2005-2007.

YEAR	Complete days	# of days [DO] <5 mg/L	# of days DO sat <75%	# of events [DO] <5 mg/L	# of events DO sat <75%
2005	92	4	14	4	19
2006	89	10	39	11	96
2007	92	8	27	8	44

Table 2. The number of days and events in which measured DO values fell below state standards.

The minimum DO % saturation values recorded for each month during 2003-07 were consistently below the standard 75% saturation value during July-September (Table 1, Figure 3), with only the July 2005 value being >75%. The minimum % DO saturation value for August 2005 was also the highest for all five years, while the September 2005 value was the second highest to the September 2004 value. This also suggests that low DO events were less pervasive during 2005 compared to the other 4 years. Similar results can be observed for monthly minimum DO concentrations values (Figure 4).

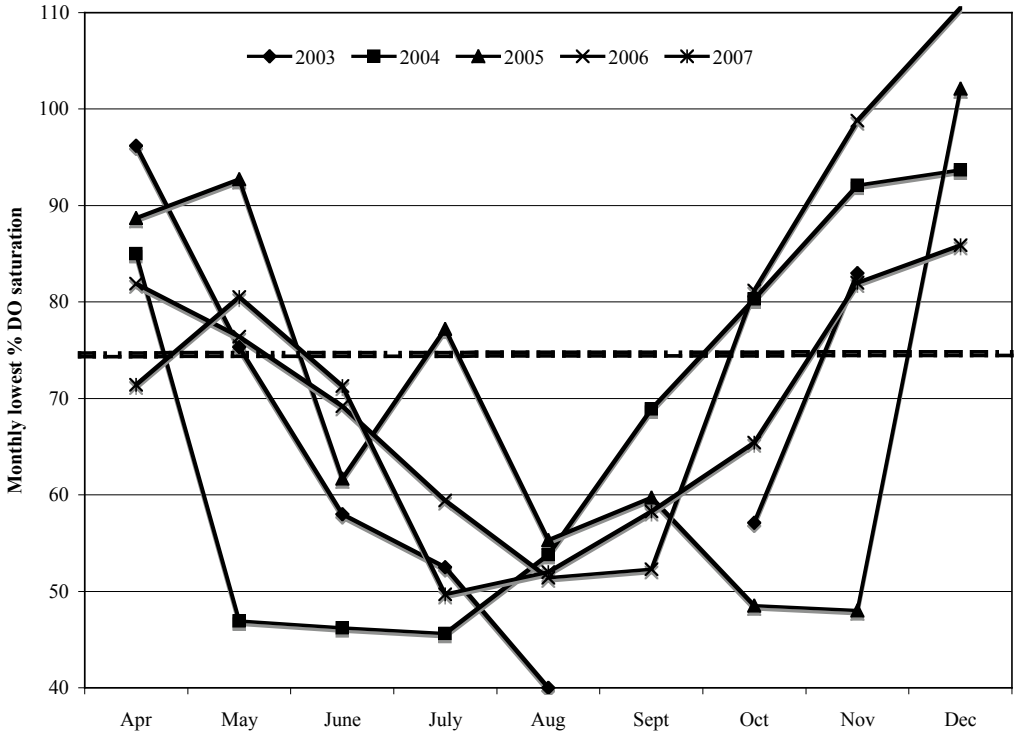


Figure 3. The lowest recorded % DO saturation values: 2005-07.

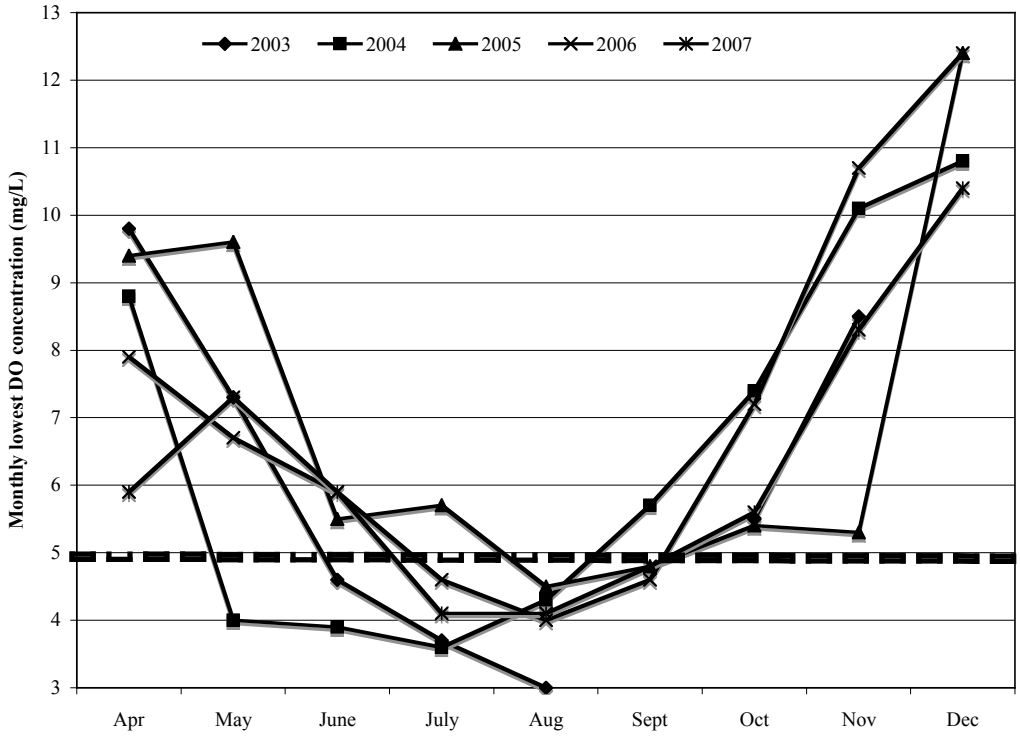
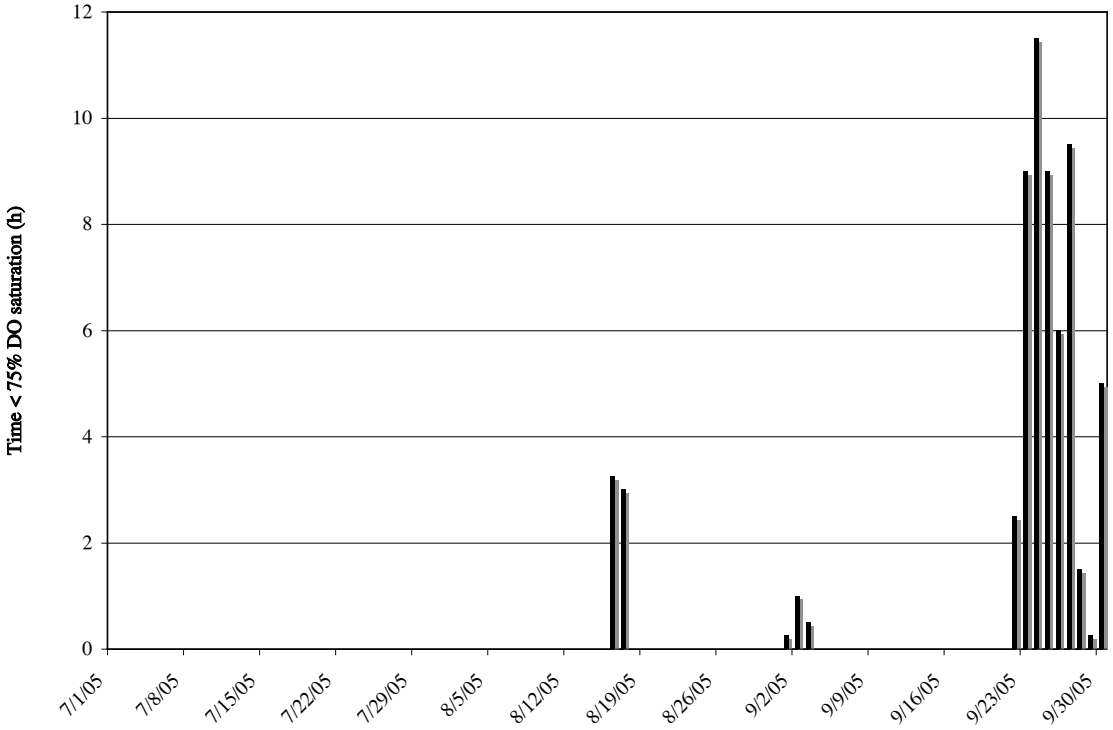
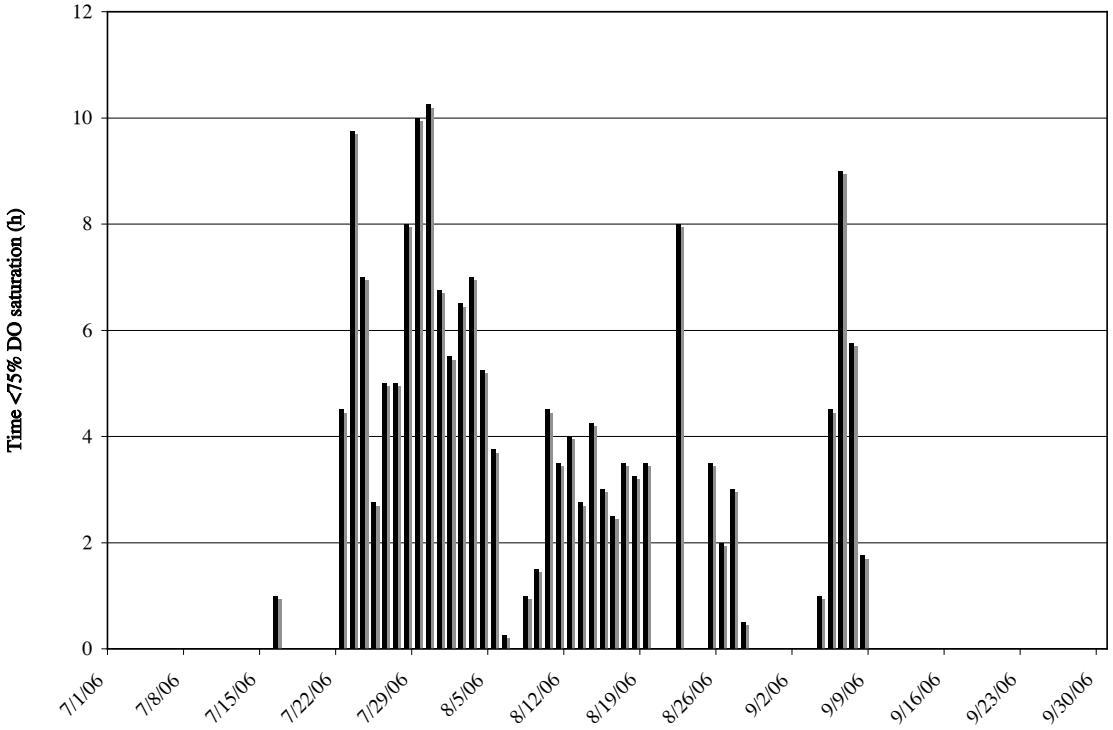


Figure 4. The lowest recorded DO concentrations values: 2005-07.

The dates on which low % DO saturation events occurred, and the cumulative daily duration of % DO saturation below standards revealed certain periods within each month in which conditions appeared to be conducive to low DO episodes (Figures 5 A-C). A comparison of these dates with the height of the data sonde suggested that low DO episodes were often associated with neap tide conditions (Figures 6 A-C), i.e., the lowest height of the sonde was relatively high on most days in which DO was low. This observation was slightly different than what was observed for sonde readings during 2003 and 2004 (Jones 2007), where a general periodicity of beginning a few days after either the spring or the neap tide was observed. For 2005-07, there were several episodes that overlapped spring tide conditions, especially during 2006 when, during a 38 day period from July 22 to August 28, only three days did not have low DO readings (Figure 6 B); note that data were incomplete and thus not used during August 20-21, yet low DO conditions were recorded on these days (data not shown). Overall, there appears to be a more discernable periodicity of low DO conditions during neap tides (less shallow sonde height) for 2005 and 2007, when low DO conditions were less pervasive and frequent. This observation can help to inform future DO studies where field measurements would be taken to determine the frequency, duration and spatial extent of low DO conditions.

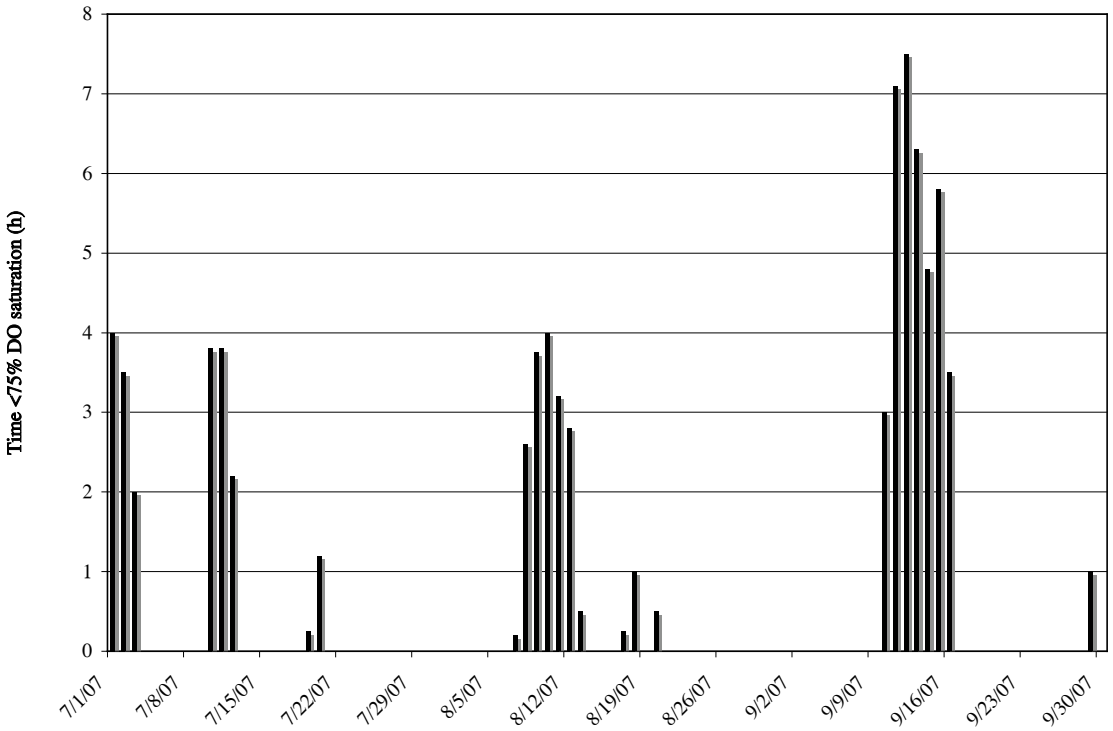

Time < 75% DO saturation (h)
12
10
8
6
4
2
0
7/1/05
7/8/05
7/15/05
7/22/05
7/29/05
8/5/05
8/12/05
8/19/05
8/26/05
9/2/05
9/9/05
9/16/05
9/23/05
9/30/05

A.

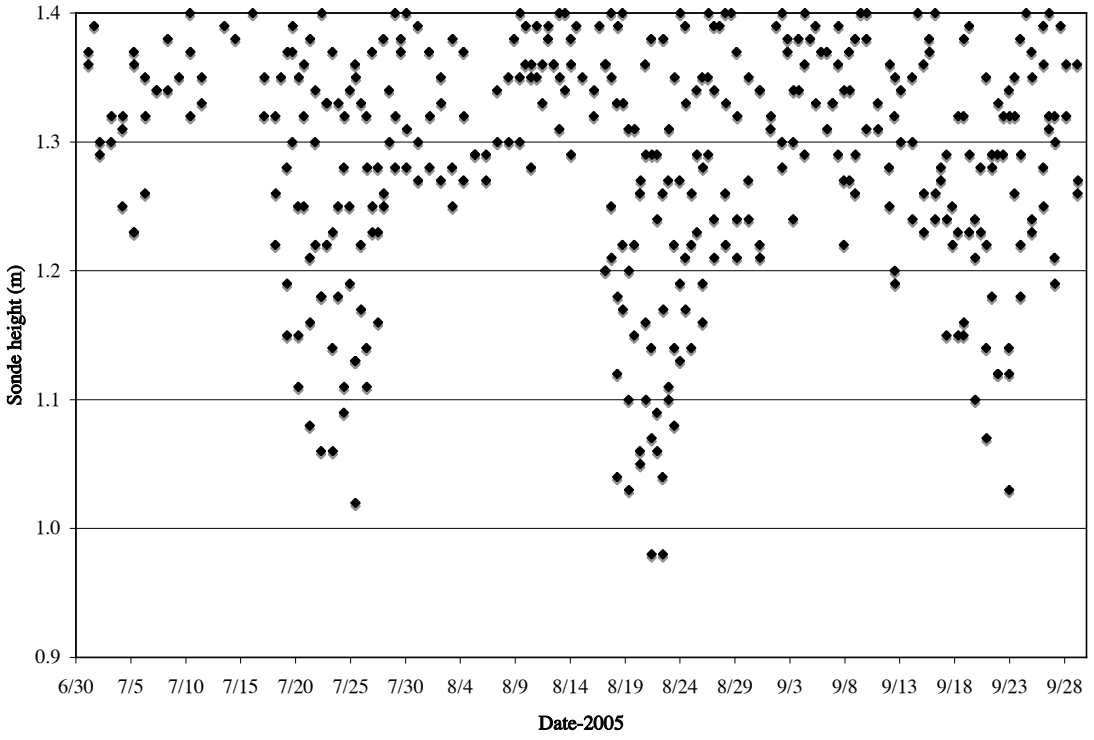

Time <75% DO saturation (h)
12
10
8
6
4
2
0
7/1/06
7/8/06
7/15/06
7/22/06
7/29/06
8/5/06
8/12/06
8/19/06
8/26/06
9/2/06
9/9/06
9/16/06
9/23/06
9/30/06

B.

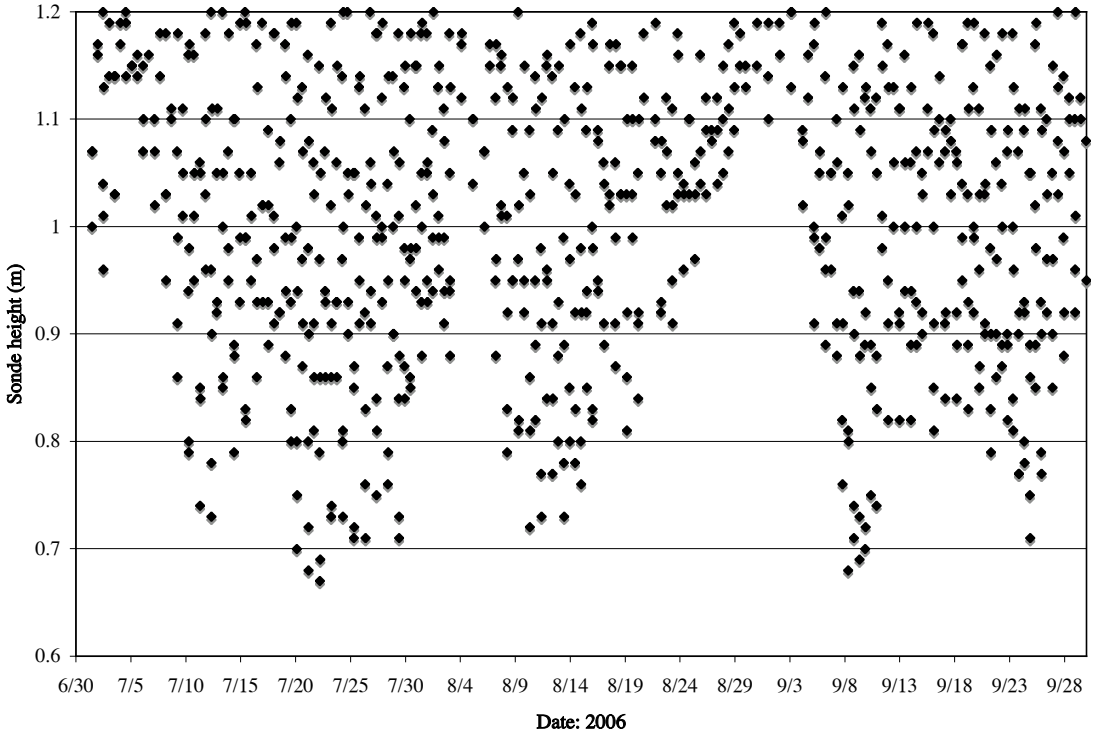
C.



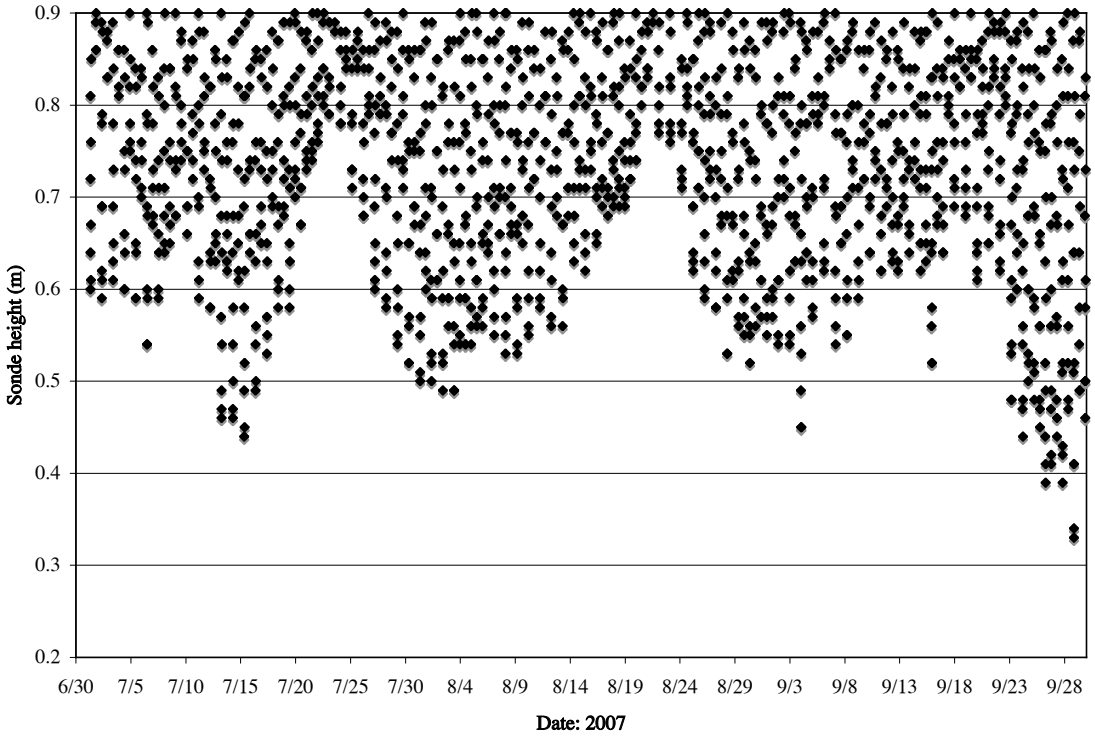
Figures 5 A-C. Dates and duration of low DO (% saturation) events for a. 2005, b. 2006, c. 2007.


Sonde height (m)
1.4
1.3
1.2
1.1
1.0
0.9
6/30
7/5
7/10
7/15
7/20
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
9/28
Date-2005

A.


Sonde height (m)
1.2
1.1
1
0.9
0.8
0.7
0.6
6/30
7/5
7/10
7/15
7/20
7/25
7/30
8/4
8/9
8/14
8/19
8/24
8/29
9/3
9/8
9/13
9/18
9/23
9/28
Date: 2006

B.



C.

Figures 6 A-C. Data sonde height range at the Squamscott River railroad bridge during low tides from July 1 to September 30: 2005-07.

The actual timing of the initiation and continuation of low DO conditions on a daily basis is also a key observation that can inform future studies on the incidence and causes of low DO conditions. The $ DO saturation and concentration data for 2005-07 were analyzed to identify the time of day when low DO events were initiated. These times were summarized for each year and organized into 4 h time intervals to determine if certain timer periods during the day were more conducive to low DO occurrence (Figure 7). The frequency (%) of low DO events that were initiated during 12:00-4:00 AM ranged from 20-50% for both % DO saturation and DO concentration for all three years, and the frequency ranged from 25-38% for the 4:00-8:00 AM time interval. The frequency for the occurrence of initiation of low DO events was much lower for other time intervals later in the day. A similar analysis was given to the time of day when the lowest DO value recorded for each day with DO less than state standards occurred (Figure 8). By far, most of the lowest daily DO values occurred from 12:00 AM to 12:00 PM, with strikingly fewer occurrences during the second half of days.

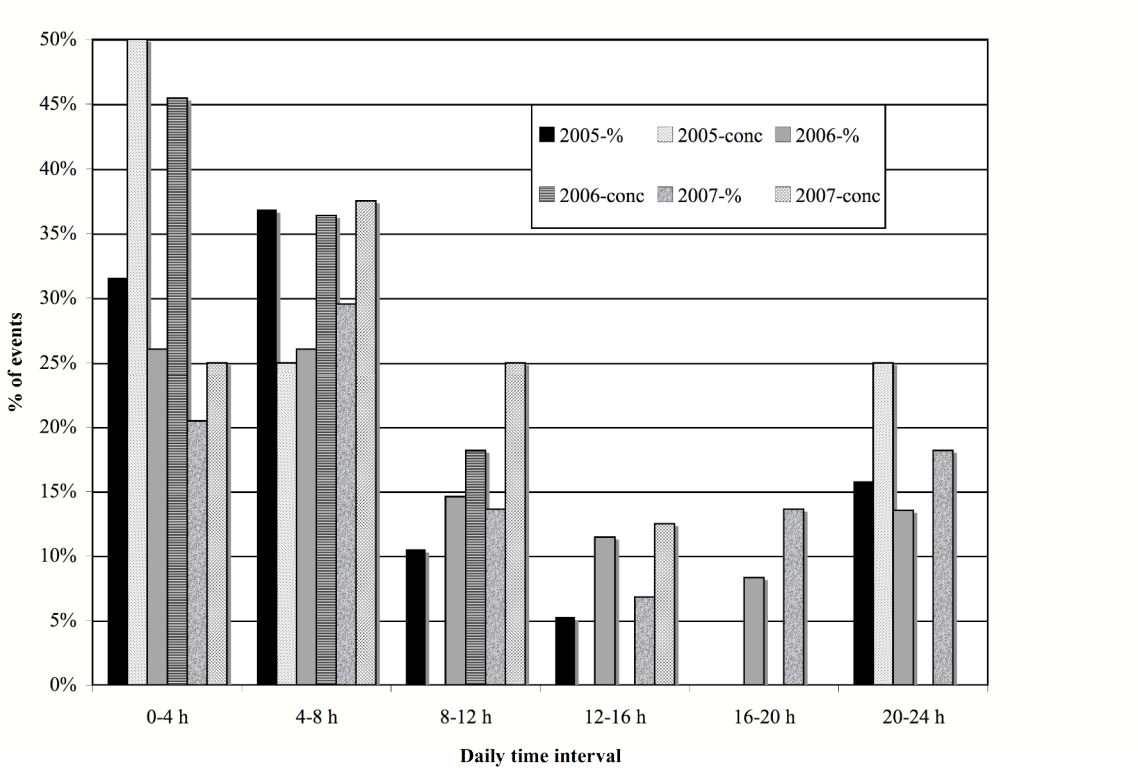


Figure 7. The frequency (%) of daily time interval when low DO events were initiated.

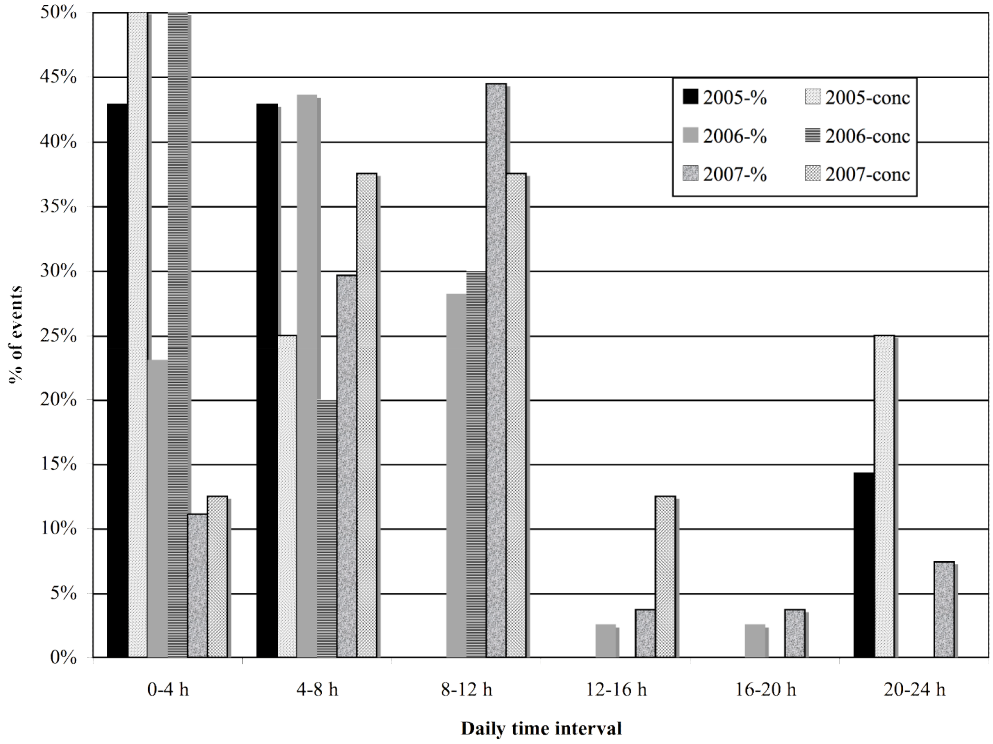


Figure 8. The frequency (%) of daily time intervals when the lowest DO values were recorded for each day.

CONCLUSIONS

This report presents the results of some detailed analysis of existing data for DO values in the Squamscott River to determine if there is a way to predict when low DO episodes occur. The results confirm that low DO episodes are most frequent and pervasive during the warmest months, from July-September each year. One question being addressed through this analysis was whether 2005 was different from other years, particularly whether low DO conditions were less frequent and pervasive. It appears that this is the case, and that the study conducted during 2005 (Jones 2007) to evaluate the spatial extent of low DO conditions was unfortunately timed during a year where low DO conditions were so infrequent that for most of the sampling dates chosen in the study, measured DO values did not fall below the state standards. In contrast, 2006 appeared to be a year in which low DO conditions were the most frequent and pervasive of the three years.

Another key to predicting when to conduct field studies is the tidal cycle conditions associated with low DO conditions. The results of this study suggest that low DO conditions may be most likely to occur during neap tide conditions, as indicated by the least shallow depth readings for the data sonde.

Beyond the seasonal and tidal time periods, it is also critical to focusing field efforts to be able to conduct studies at the most critical time of day. The widely accepted time period of near sunrise appears to be borne out by the results of this study. The most frequently observed time of day when either a low DO event was initiated or the lowest DOI reading was recorded was in the morning, especially before 8:00 AM. Much less frequent occurrence of these events was observed during the second half of days.

It appears that the predicted conditions for conducting water measurements and sampling during 2005 were relatively accurate. The study could have been more successful except that 2005 was a year in which low DO episodes were less frequent and pervasive. Future studies in the Squamscott River area near the data sonde can benefit from use of the results reported herein. The same kind of analysis could also be used to help inform studies in other areas of the estuary where data sondes are nearby and there are available databases for water quality conditions.

RECOMMENDATIONS

1. Conduct DO studies during July-September, especially during August.

2. The timing of field studies on the Squamscott River should be during neap tides and during early to mid-morning hours.

REFERENCES

Jones, S.H. 2007. Impacts of Wastewater Treatment Facilities on Receiving Water Quality. Final Report. The New Hampshire Estuarine Project, Durham, NH.

Jones, S.H. 2005. Survey of dissolved oxygen in the Lamprey and Squamscott rivers.Summary report. Office of Research and Development, Atlantic Ecology Division, U.S. Environmental Protection Agency, Narragansett, RI.

Trowbridge, (2006) NHEP Environmental Indicator Report: Water Quality 2006. The New Hampshire Estuarine Project, Durham, NH.

APPENDICES

Appendix 1: Summary Table for data related to low DO events

DATE	Duration	Time of initiation	DO%	low DO%	initiation	[DO]	low [DO]
2005							
8/16/05	3, *						
8/17/05	3	2:30, 16:00	58.9	4:00	4:00	4.7	4:00
9/1/05	*				4:30	4.5	5:00
9/2/05	1	6:30	71.6	6:30			
9/3/05	0.5	6:30	70.4	7:00			
9/22/05	2.5	21:30	61.6	23:00			
9/23/05	1,7,2	5:30,22:00	62.9	23:30			
9/24/05	2.5,8.5,0.5	4:30,23:30	59.7	0:30			
9/25/05	2.5,2	11:30	63	1:00	23:00	4.9	23:00
9/26/05	3.5,*,*,2	0:00,8:00,9:00	64.5	2:00			
9/27/05	9.5	0:00	65.8	3:00	0:00	4.8	0:30
9/28/05	1.5	3:30	70.8	4:00			
9/29/05	*	5:00	73.6	5:00			
9/30/05	5	2:30	69.5	5:30			
2006							
7/16/06	1	8:30	74.1	9:00			
7/22/06	4.5	14:30, 18:00	72.3	15:00			
7/23/06	7, 2.5, *	2:00, 14:30, 19:30	60.5	6:30	4:30	4.8	5:00
7/24/06	7	2:30	62.3	5:30			
7/25/06	2.5, *	4:00, 9:30	68.4	6:00			
7/26/06	5	5:00	69.8	7:00			
7/27/06	5	5:30	66.7	7:30			
7/28/06	5, 3	6:00, 20:00	66.4	8:00			
7/29/06	6.5, 3.5	5:30, 20:30	59.7	9:00	7:30	4.6	9:00
7/30/06	*, 6.5, 3.5	6:00, 21:30	59.4	9:30	7:30	4.6	9:00
7/31/06	*, 5.5, 1	7:00, 23:00	65.1	10:00			
8/1/06	*, 5, *	8:00, 23:30	66.5	11:30			
8/2/06	1.5,4.5,.5	9:00, 23:30	63.7	1:00	1:00	4.9	1:00
8/3/06	2.5,*,4,*	8:00, 10:;30, 13:30	68.2	2:00			
8/4/06	.5,*, 4.5	1:00, 3:00, 10:30	66.1	11:30	11:30	4.9	11:30
8/5/06	*, 3.5	0:30, 1:30	69.9	4:00			
8/6/06	*	5:00	72.3	5:00			
8/8/06	.5,*,*	4:30, 6:30	73.6	6:30			
8/9/06	1,*,*	5:00, 7:00, 9:00	71.8	5:30			
8/10/06	4.5	5:30, 9:30	68.8	6:30			
8/11/06	3,*,*	6:00, 10:30, 22:30	67.1	6:30			
8/12/06	3.5,*,*	6:00, 20:30, 23:30	66.7	8:00			
8/13/06	*,2,*,*	7:00, 12:00, 23:00	68	8:30			
8/14/06	.5,1,2.5,*	0:30, 4:30, 7:00, 11:30	66.5	5:00			
8/15/06	.5,*,1.5,*,.5	0:00, 1:30, 9:00, 13:30, 23:00	69.5	1:30			
8/16/06	2,*,*	1:00, 11:00, 13:30	64.1	1:00			
8/17/06	*,2.5,***	0:00, 1:30, 8:00, 15:30, 20:30	62.4	2:00	2:00	4.9	2:00
8/18/06	*,2.5,.5	1:00, 2:30, 8:30, 15:30	54.7	3:30	3:00	4.3	3:30
8/19/06	.5,2.5,*,*	2:00, 3:30, 16:30, 22:00	59.7	4:00	4:00	4.6	4:00
8/20/06	data incomplete						
8/21/06	data incomplete						
8/22/06	0.5, 7.5	0:00, 3:00	57.7	0:30	0:00, 8:30	4.4	0:30
8/25/06	3, 0.5	6:30, 19:00	64.9	9:00			
8/26/06	2	6:30, 19:30	66.4	9:30			
8/27/06	3	7:00, 20:00	19:12	8:30			
8/28/06	*,*	7:30, 21:00	68	10:30			
9/4/06	0.5, 0.5	0:30, 14:30	57.1	4:30			
9/5/06	2.5, 2	2:30, 14:30	62.1	5:30			
9/6/06	*, 5.5,1.5,*,2.5	0:00, 2:00, 9:00, 12:30, 15:30	61.6	18:30			
9/7/06	*, 5.5	0:30, 3:00	52.3	7:00	7:00	4.6	7:00
9/8/06	1.5, *	5:30, 19:30	68.1	7:30			
2007			2007				
7/1/07	3.5, 0.5	6:30, 20:15	69.3	8:30			
7/2/07	3.2, *	7:15, 21:15	68	9:00			
7/3/07	2	8:45	71.5	9:30			
7/10/07	3.8	1:45	71.5	5:00			
7/11/07	3.8	2:45	70.3	6:00			
7/12/07	1.2,0.7,0.3	3:45,6:45,9:30	49.7	9:30	9:30	4.1	9:30
7/19/07	0.25	23:30	74.6	23:30			
7/20/07	*, 1	0:15,9:30	74.4	10:00			
8/7/07	*	2:15	73.6	2:15			
8/8/07	1.8, 0.8	2:30,14:45	64.4	3:15	3:15	4.8	3:15
8/9/07	3.25, 0.5	2:45,16:00	55.3	4:30	3:15	4.1	4:30
8/10/07	2.8, 1.2	4:00,16:45	61.3	5:15	4:45	4.6	5:15
8/11/07	3, *	4:45,18:30	62	6:15			
8/12/07	2.8	5:45	66.4	7:15			
8/13/07	0.5	8:00	73.6	8:00			
8/17/07	0.25	12:45	52	12:45	12:45	4.5	12:45
8/18/07	0.25,0.75	11:00,23:15	71.2	23:45			
8/19/08	1.8	10:30	66.9	11:30			
8/20/07	0.5	0:15	72	0:30			
9/10/07	1, 2	6:30,18:00	71.3	19:00			
9/11/07	3.8, 3.3	5:30,18:00	62.7	7:30	7:30	4.9	7:30
9/12/07	4.5, 3	5:15,18:45	58.3	8:15	8:00	4.8	8:15
9/13/07	3.5, 2.8	6:30,19:45	58.5	8:45	8:30	4.9	8:30
9/14/07	2.8, 2	7:30,20:45	63	9:15			
9/15/07	2.5, 3.3	8:15,20:45	66.7	10:00			
9/16/07	*, 3, *	8:00,23:15	70.5	10:15			
9/29/07	1	7:45	74.4	8:15			

*Denotes low DO events where a single sonde datum were recorded for a given event.