East-Flowing Rivers Baseline Water Quality Survey

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SUMMARY

A general water quality survey was carried out at three rivers, the Pereaux, Habitant and Canard, during the period between 16 May and 28 August 2001. All three rivers are located in the eastern part of the Annapolis Valley, Nova Scotia and flow eastward into the southern bight of the Minas Basin, Bay of Fundy. The water quality parameters measured included suspended particulate matter, water temperature, hardness, pH, alkalinity, dissolved oxygen, total phosphorous, nitrate, chlorophyll *a* and coliform bacteria.

Although there was considerable variation among the rivers, both spatially and temporally, in many of the parameters monitored, all exhibited evidence of impaired water quality. Water temperatures were high in the Habitant and Canard Rivers, particularly in the lower reaches. Phosphorous and nitrogen levels were also high in all of the Rivers, and fecal coliform bacteria were usually above levels suitable for most uses.

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1. Introduction

The recent series of unusually hot, dry summers in Nova Scotia has resulted in the growing use of many rivers and their tributaries for irrigation of agricultural crops. This is especially true within the Annapolis Valley where soils are relatively sandy and have limited capacity for retaining moisture over long periods. In many cases there is little or no information or monitoring of water quality in these water bodies, especially for the smaller rivers. In the case of the Canard, Habitant and Pereaux Rivers, all of which are currently being used for crop irrigation, there have been no significant studies of water quality and no data exist that allow an assessment of the water quality of these Rivers. The objective of this study was to carry out a basic water quality survey that would provide information useful to resource managers concerned with the water quality of these three Rivers, not only with respect to crop irrigation, but also other activities such as livestock watering, fisheries, and recreational uses.

2. Approach

Each of the three Rivers was sampled at bi-weekly intervals between 16 May and 28 August 2001. The number of stations sampled on each River varied with the length of the River. The Habitant and Canard Rivers, each of which has a main stem of about 12 km, were sampled at six and five sites respectively. The Pereaux, which has a main stem less than 4 km in length, was sampled at three sites for most parameters, but was sampled at four sites for coliform numbers. The location of each sample station is indicated in Figure 2.1.

The water quality parameters measured were those typically used in general water quality assessments. These included: total suspended particulate matter (both inorganic and organic); water temperature; conductivity; total, calcium and magnesium hardness; alkalinity; pH; dissolved oxygen; percent dissolved oxygen saturation; total phosphorus; nitrate; chlorophyll *a*; and total and fecal coliform numbers. Some, but not all, of these parameters have guidelines established by the Canadian Council of Resource and Environment Ministers (1996) with respect to acceptable levels for various uses and, when possible, these guidelines were used to draw conclusions regarding the water quality of each River.

3. Methods

Temperature, conductivity and pH were measured in the field using a Horiba U-10 Water Quality Checker. Water samples for dissolved oxygen were collected with a Van-Dorn water sampler, transferred into 300 ml BOD bottles and fixed in the field. Analysis of dissolved oxygen was carried out using the Winkler procedure (American Public Health Association 1989). Total, calcium, and magnesium hardness and nitrate were measured using HACH (1989) procedures.

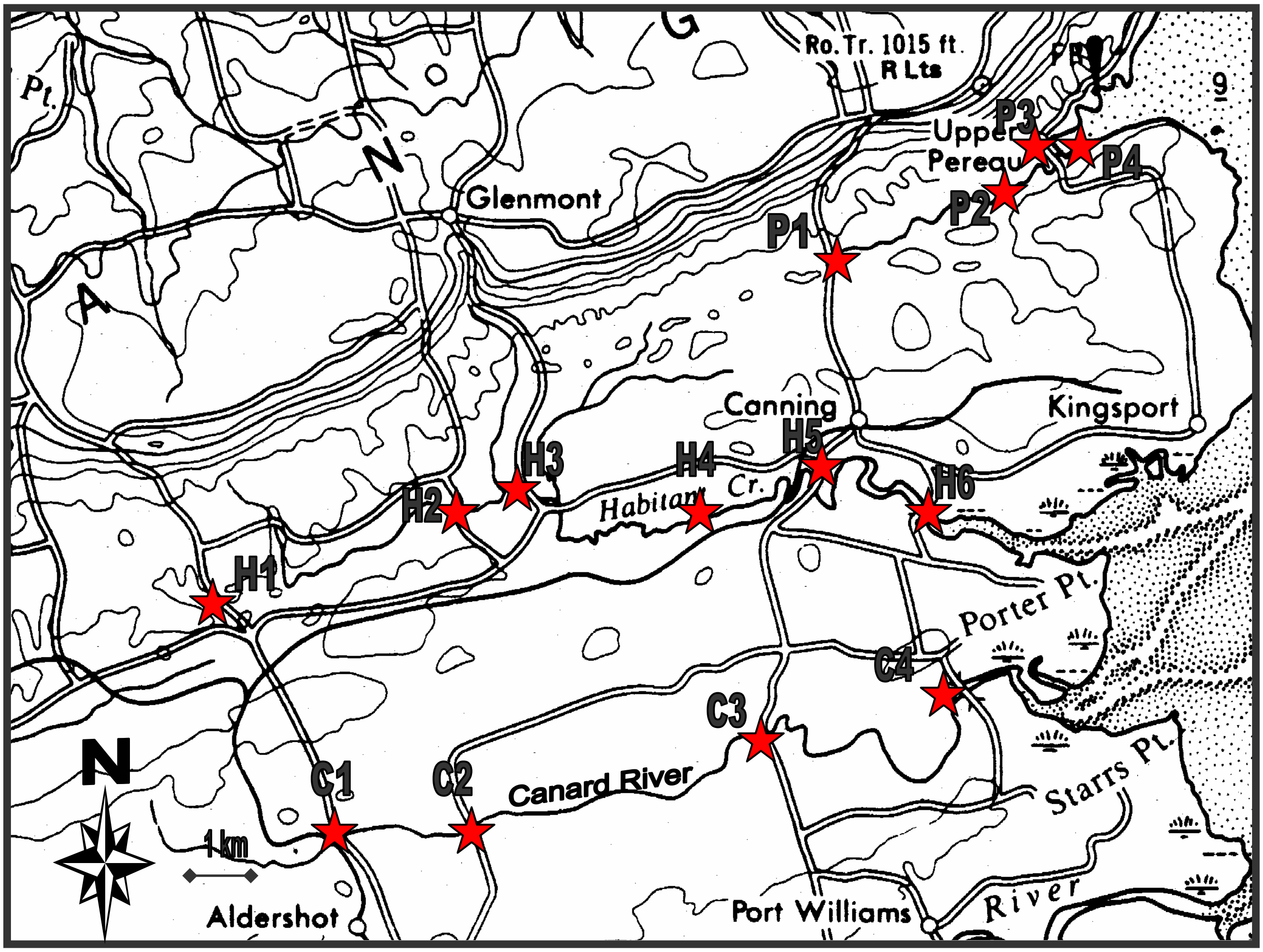

Figure 2.1. Location of sample stations.

Water samples for total phosphorous were collected in acid washed polyethylene bottles and stored refrigerated until analysis. Samples were analyzed within 24 hr of sample collection using the molybdate-blue method as described in Wetzel and Likens (1991).

Total suspended particulate matter (TSPM) determinations were made by filtering 1 litre water samples through pre-combusted Watman GF/C glass fiber filters and oven drying the filters at 60-70 ºC to a constant dry weight. Suspended particulate inorganic matter (TPIM) was determined after combustion of the filters at 500 ºC for 3 hr and reweighing the filters. Suspended particulate organic matter (TPOM) was determined as the difference between total particulate matter and particulate inorganic matter.

Samples for phytoplankton chlorophyll *a* measurements were collected in 1 litre polyethylene containers and stored refrigerated until analysis (usually within 24 hr of collection). The samples were filtered through Watman GF/C filters under gentle vacuum (<20 mm Hg) and chlorophyll extracted from the filters by adding 18 ml of 95 percent acetone and storing the samples refrigerated in the dark for 24 hr. After extraction the samples were centrifuged at 2500 rpm for 5 min, decanted into a 5 cm path length cuvette and absorption measured spectrophotometrically at 665 and 750 ηm before and after acidification with 0.1 ml of 10 percent HCl. Chlorophyll *a* concentrations were calculated according to the equations presented by Wetzel and Likens (1990).

Total coliform and fecal coliform numbers were collected in pre-sterilized sample containers. Samples were kept cool and in the dark after collection and delivered, on the day of collection, to the microbiology laboratory of the Valley Regional Hospital in Kentville for analysis.

Water levels were measured at all stations using a meter stick and, when water depths were sufficient, current velocities were measured at stations P2, H4 and C3 on the Pereaux, Habitant and Canard Rivers respectively, using a Geopacks model MJP stream flow meter.

4. Results and Discussion

A complete listing of all data collected and graphical summaries are contained in the Appendices. Appendix I contains a listing of the water quality measurements made at each station over the entire study period. Appendix II contains time series plots of the value of each parameter at each station over the entire sampling period.

On each River, the most downstream sampling station was located immediately upstream of an aboiteau containing a tidal gate that controls the entrance of seawater into the river during flood tide. During the course of the survey it became evident that all of these gates leak seawater to some extent. Consequently, many of the water quality parameters measured at these stations differed greatly from those measured at locations further upstream. Because this was a very localized phenomenon, and water quality at these stations was very atypical, most of the general descriptions presented below apply only to the stations located upstream of the aboiteau.

4.1 Water Levels and Discharge

The last half of the study period included a period of very dry weather (Table 4.1.1 and Figure 4.1.1). Total rainfall recorded between 1 May and 31August at the Agriculture Canada Research Centre in Kentville amounted to 256.6 mm, over half of which fell during the first half of May. The total amount of rainfall during July and August was only 38.5 mm. The forty-year average reported for this same time period at Kentville is 160.9 mm. Consequently, water levels decreased to extremely low levels during the later part of the study.

Attempts to monitor water discharge rates the Canard and Habitant Rivers were unsuccessful. The flow of water at the sites chosen for measurements of water depth and current velocity became braided as a result of the low water levels during the dry period, which prevented making accurate measurements of depths and current velocities. (Discharge rates for the Canard River, however, should become available as they were being measured as part of comprehensive hydrology study of the Canard being carried out by others over the same time period.)

Although water levels in the Pereaux River also fell during the dry weather, a 1.5 m wide box culvert under the roadway to Blomidon served as an ideal site for measurement of depths and current velocities, even at times of very low water levels. The seasonal variation in calculated discharge rates for The Pereaux is illustrated in Figure 4.1.2.

Table 4.1.1. Total precipitation during each month of the study period and comparison with 40-year average.

Month	Total Precipitation (mm)	
	2001	1961-2000 Average
May	137.7	77.4
June	80.4	67.2
July	27.0	70.1
August	11.5	90.8
TOTAL	**256.6**	**305.5**

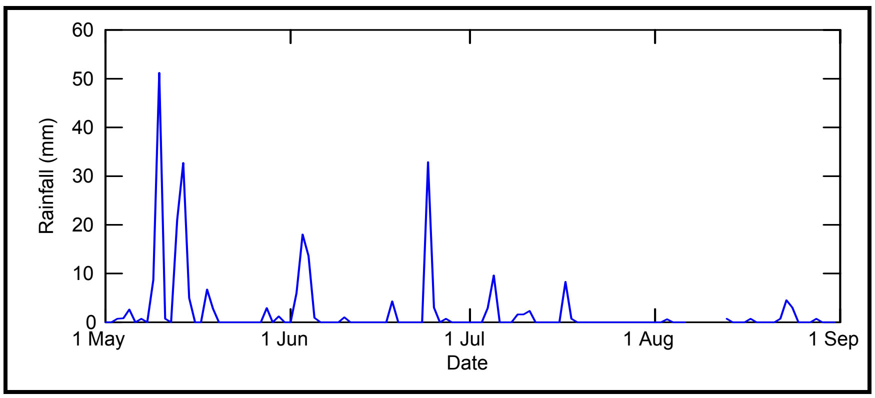

Figure 4.1.1. Daily precipitation recorded at the Agriculture Canada Research Station, Kentville, N.S. during the period of the water quality survey.

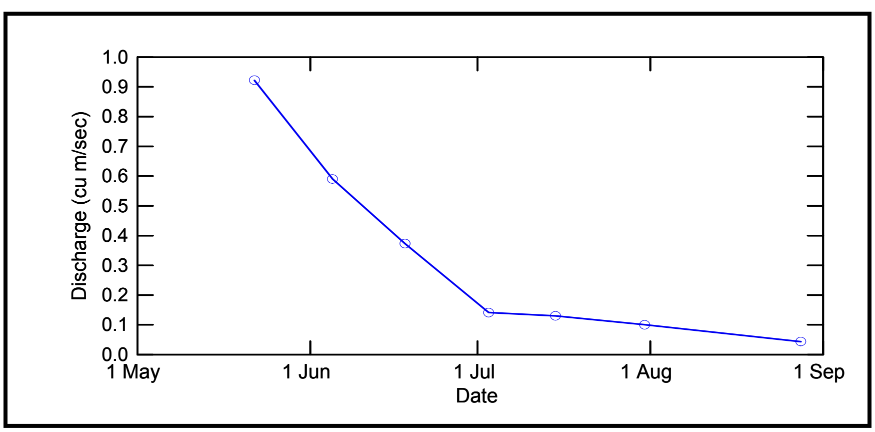

Figure 4.1.2. Seasonal variation in water discharge at station P2 on the Pereaux River during the period of the water quality survey.

4.2 Suspended Particulate Matter

Total Suspended Particulate Matter (TSPM) is a measure of the quantity of solids suspended in the water. The solids may be either inorganic (TPIM) or organic (TPOM). High levels of TPIM usually indicate land erosion within the drainage basin and the presence of suspended sands, silts, or clays. High levels of TPOM typically indicate high amounts of organic materials from biological production within the water column, or organic inputs such as inadequately treated sewage or food processing effluents. TSPM values in natural, undisturbed systems are typically less than 10 mg/l.

In general, there was little difference among the Rivers in the mean level of TSPM over the entire survey period (Figure 4.2.1). Values were low most of the time seldom exceeding 10 mg/l. However, while TSPM values were always low in the Pereaux River, some high values were observed in both Canard and Habitant Rivers (FigureA1, Appendix II) during the earlier part of the survey when precipitation was greatest. Some of these values exceeded 15 mg/l suggesting sediment erosion problems in these systems. The generally low values observed at other times may be more a result of the lack of precipitation, and therefore surface run-off, than evidence of the absence of sediment erosion. In most cases TSPM consisted of about equal quantities of organic and inorganic matter.

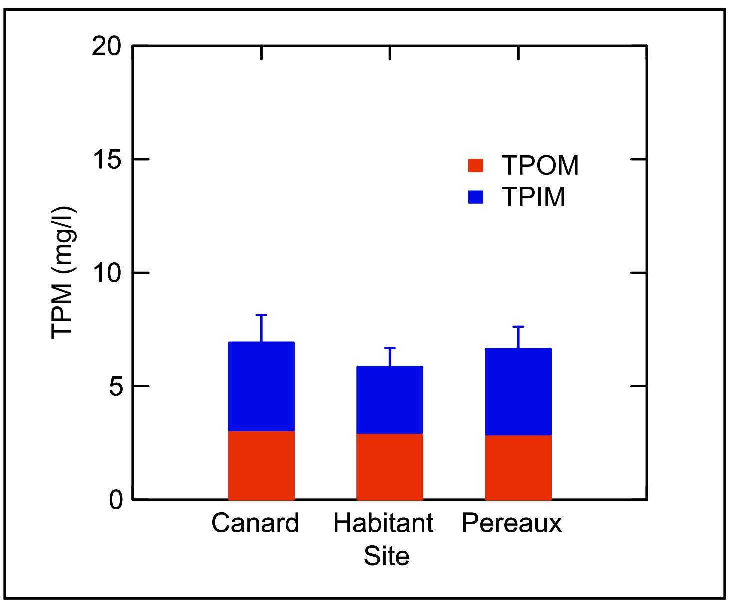

Figure 4.2.1 Mean value of suspended particulate matter for each site (error bars are one standard error of the mean).

4.3 Water Temperature

Spatial and temporal variations in water temperature provide information on the suitability of a river to support cold-water fish species such as salmonids. It is also important in determining the amount of oxygen dissolved in the water, as well as the rate at which dissolved oxygen is utilized by microorganisms in decomposing organic matter. The capacity of water to dissolve oxygen decreases as water temperature increases, and the metabolic rate of microorganisms increases with temperature.

Water temperature is influenced by the source of water and the nature of the riparian zone (the land area adjacent to the river). Spring fed rivers generally have colder water than those receiving water largely via surface runoff. The nature of the riparian zone is also important in determining the degree to which solar energy heats the water. A well-vegetated riparian zone shades the river and reduces heating of the water.

There was considerable variation in temperature among the three Rivers (Figure 4.3.1). The mean water temperature at all stations for each River was 12.4, 15.8 and 17.7 ºC for the Pereaux, Habitant and Canard respectively, and the maximum summer temperature recorded at each River was 13.8, 21.1 and 19.1 ºC for the Pereaux, Habitant and Canard respectively. Water temperatures in the Pereaux River were surprisingly low and varied little, either spatially or seasonally (Figure A2, Appendix II). The Pereaux is a short river and appears to be largely spring fed. In addition, it appears to be relatively more shaded by streamside vegetation than the other two Rivers. Water temperatures in the Canard and Habitant showed more spatial variation with significant increases in temperature from headwater to downstream stations. Increases of 10-12 ºC were typical for the Habitant. The Canard had increases in the range of 8-10 ºC.

Water temperatures in the Pereaux River are quite suitable for cold-water fish species. Water temperatures in the Canard and Habitant Rivers are only marginal in this respect.

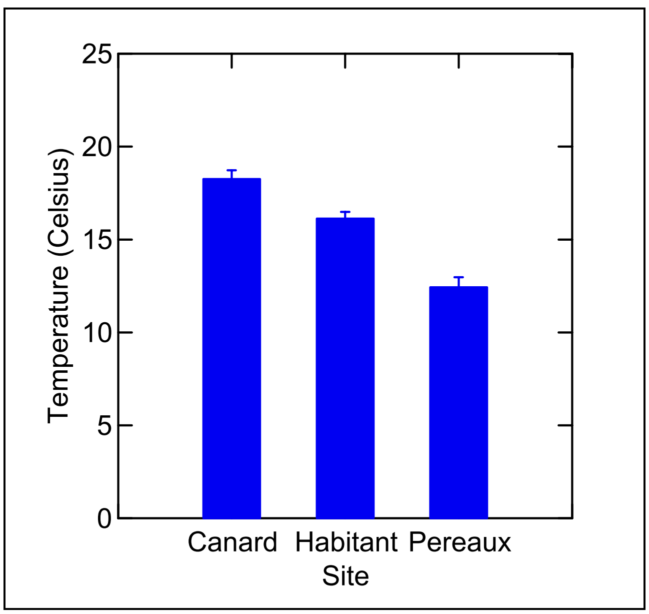

Figure 4.3.1 Mean water temperature at each site (error bars are one standard error of the mean).

4.4 Total Hardness, Conductivity, Alkalinity, and pH

Total hardness, conductivity, alkalinity and pH are all related in that their values are determined largely by the kinds and quantities of dissolved salts present. High concentrations of dissolved salts results in hard water, which is typically characterized by high conductivity, high alkalinity (buffering capacity) and high pH. Regional variations in these parameters most often result from variations in geology. Water bodies located in geological formations that weather slowly, such as granite and basalt, generally contain low levels of dissolved salts and therefore soft water. In contrast, water bodies located in geological formations more susceptible to weathering, such as sandstone, typically have high salt contents and hard water. Soft waters are characterized as those having total hardness vales less than 100 mg/l. Hard waters are generally considered to be those having total hardness levels greater than 300 mg/l.

There is considerable variation in the mean levels of all of these parameters among the three Rivers (Figure 4.4.1). Total hardness for the Canard River is in the range of 50-60 mg/l, which is indicative of relatively soft water. The Pereaux River has the highest hardness values with a mean of about 170 mg/l, and the Habitant River is intermediate with a mean of about 150 mg/l. Calcium is the major salt in all of the Rivers.

The differences in hardness among the three Rivers are most likely due to the relative contributions of spring water versus surface runoff. Because spring water percolates through the soil, it often contains higher levels of dissolved salts than does surface runoff water. As a result, spring fed systems will have higher dissolved salt levels. The spatial and temporal trends observed for hardness levels (Figure AX, Appendix II) are similar to that observed for temperature (see Section 4.3), which is also influenced by the relative contribution of spring water.

Alkalinity is reasonably high in all of the Rivers indicating they all have substantial buffering capacity and the ability to offset the negative affects of acid precipitation. This is also reflected in the relatively high pH levels, which were always above the neutral value of 7.

Values of pH remained relatively constant, both over the study period and with distance downstream, for all of the Rivers. In contrast, there was considerable variation in the spatial and temporal changes of conductivity, total hardness and alkalinity. Within the Pereaux River, values increased over the study period, but there was little variation with distance downstream. Values for the Habitant and Canard generally increased over the study period as well with distance downstream.

4.5 Dissolved Oxygen

Dissolved oxygen is essential for most aquatic life. Concentrations below about 5 mg/l are considered stressful. Another indicator of the availability of dissolved oxygen is percent dissolved oxygen saturation, a function of both the absolute amount of dissolved oxygen and water temperature. Most aquatic organisms become stressed when dissolved oxygen saturation falls below 50 percent.

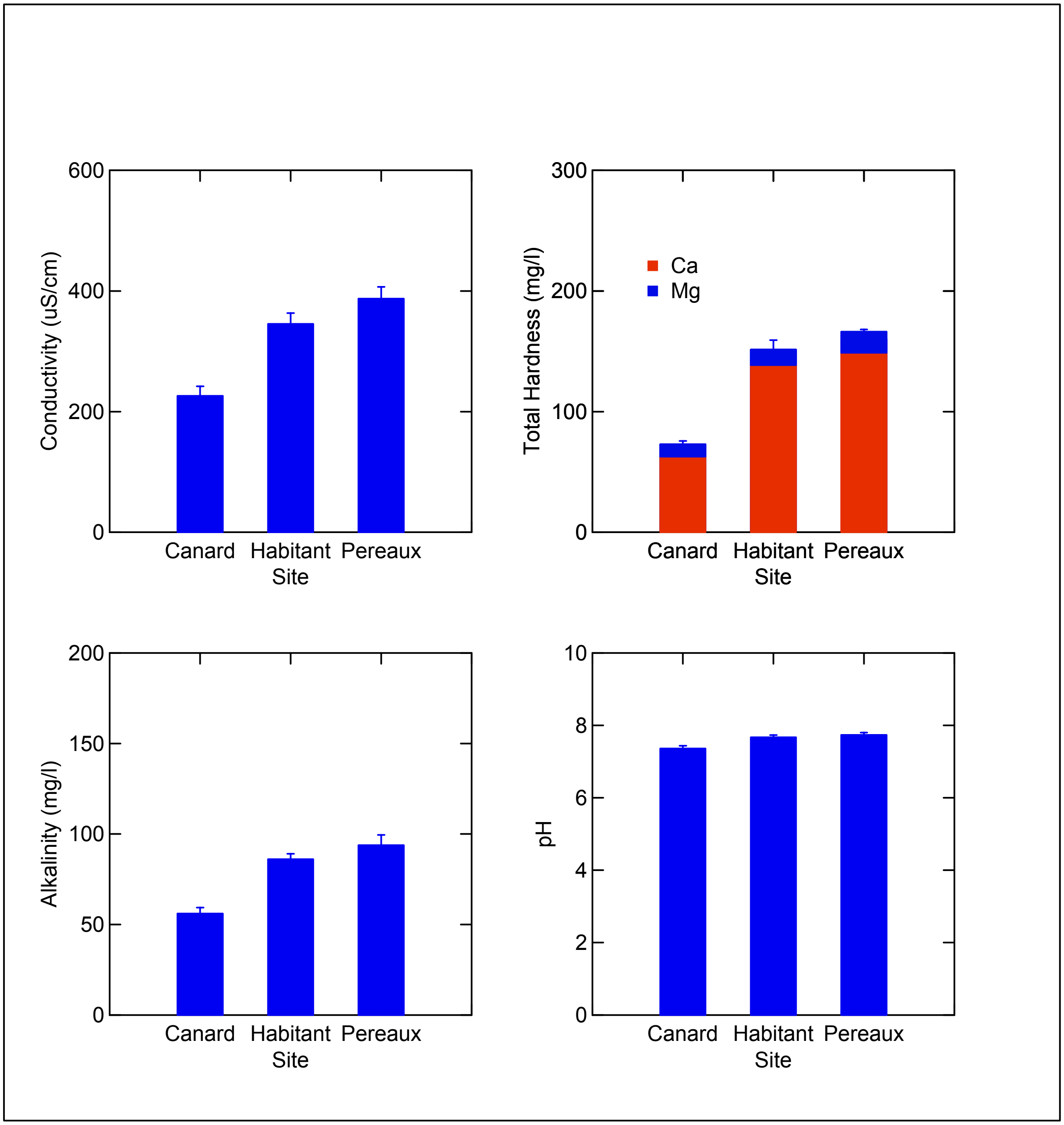

Figure 4.4.1. Mean values of conductivity, hardness, alkalinity and pH for each site (error bars are one standard error of the mean).

Dissolved oxygen levels and percent saturation values were high at all sample stations in the Pereaux River, but varied considerably in the Canard and Habitant Rivers (Figure 7A, Appendix II). The lowest values were observed in the upper part of the Canard, many of which were near and sometimes below the 50 percent saturation level. A few instances of low dissolved oxygen values were also observed in the Habitant, but these never fell below the 50 percent saturation level. In some cases dissolved oxygen levels in the Canard and Habitant Rivers were well above the 100 percent saturation level. This typically occurred in the lower portions of the Rivers and is probably a result of either heating of the water or production of oxygen by photosynthesis of aquatic plants.

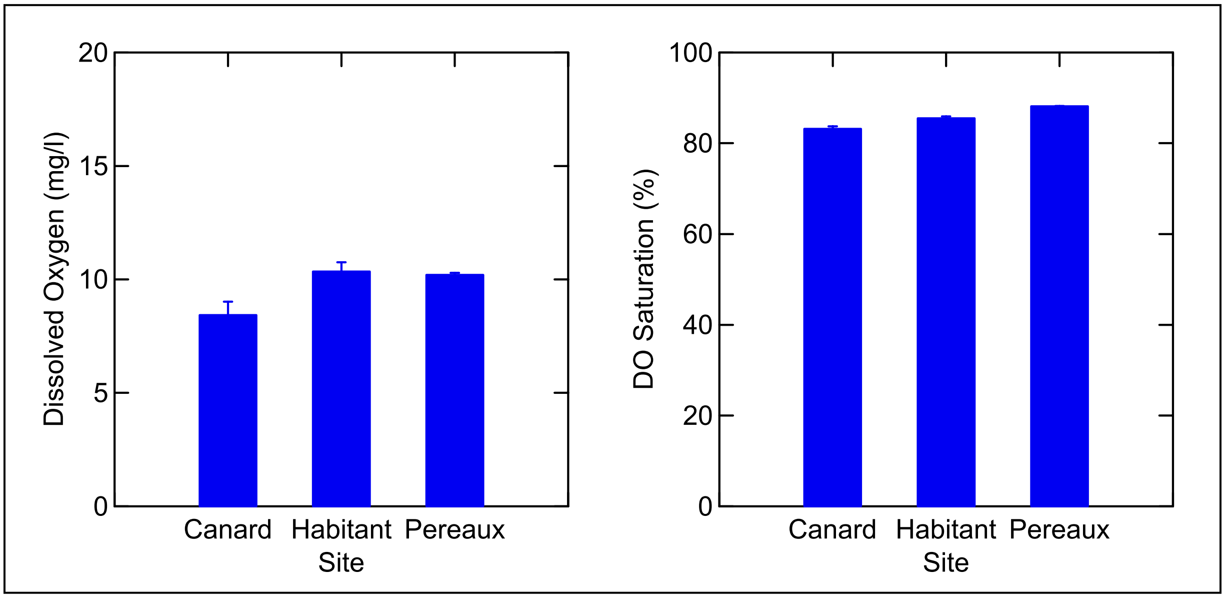

Figure 4.5.1 Mean values of dissolved oxygen and percent dissolved oxygen saturation at each site (error bars one standard error of the mean).

4.6 Total Phosphorous and Nitrate

Phosphorous and nitrogen are the two most important micronutrients required for the growth of aquatic plants. They are also the nutrients that, when present in high quantities, cause aquatic systems to become eutrophic. The term 'eutrophic' refers to aquatic systems that have excessive plant growth and, consequently, low dissolved oxygen levels as a result of the decomposition of the plant material. Eutrophic systems often also contain high levels of toxic substances such as methane, ammonia and hydrogen sulfide, the by-products of organic decomposition under anoxic or anaerobic conditions. Eutrophication is most common in standing water systems such as ponds, lakes and coastal bays. Small rivers and streams are usually well aerated due to the turbulence created by running water and, as a result, seldom become anaerobic. It is generally believed that excessive phosphorous input is the factor responsible for eutrophication of fresh water systems, while excessive nitrogen input is the cause in marine systems. Levels of total phosphorous above about 0.02 mg P/l will cause eutrophic conditions in standing water systems. Nitrate levels above 1 mg N/l are considered high and can also lead to eutrophic conditions.

The levels of phosphorus and nitrogen were high in all of the Rivers, but varied greatly among the three Rivers (Figure 4.6.1). The Canard River had very high phosphorous levels, but the lowest nitrate levels. The opposite was true for the Pereaux River where nitrate was much higher than phosphorous. In the Pereaux and Habitant Rivers, nitrate levels generally increased both downstream and over the study period. In the Canard River, nitrate levels varied little either spatially or temporally.

The source of these nutrients in the Habitant and Pereaux Rivers is most likely from leaching of agricultural fertilizers. This may also be true of the Canard, but two sewage treatment plants, one located near Aldershot and one located just east of Highway 341, probably also contribute substantial quantities of these nutrients. Although, based on dissolved oxygen levels (see Section 4.5), there did not appear to be any evidence of eutrophic conditions in any of the Rivers during the study period, many areas have extensive growths of aquatic macrophytes such as watercress and duckweed, as well as filamentous algae attached to substrates. This is especially true of the Canard, and the uptake of nitrate by this vegetation may explain why it has such low nitrate levels.

If water from any of these rivers were to be impounded, it would surely result in eutrophic conditions.

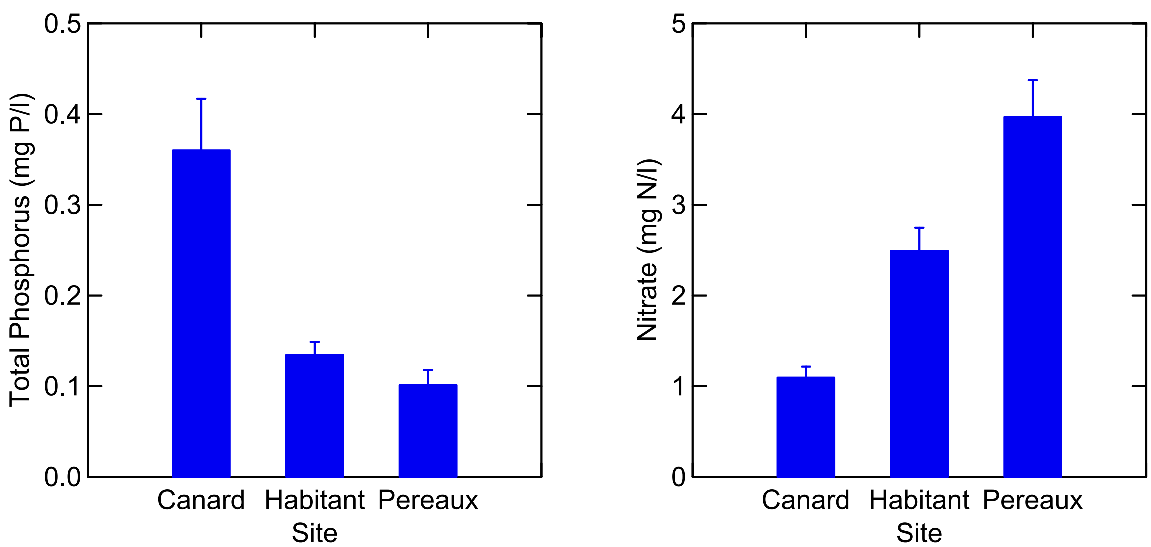

Figure 4.6.1 Mean total phosphorous and nitrate levels for each site (error bars are one standard error of the mean).

4.7 Chlorophyll *a*

Chlorophyll *a* concentration, a relative measure of the amount of plant biomass contained in a water sample, is most commonly used in assessing the water quality of standing water systems and is not traditionally measured in flowing water systems. However, because the rivers being surveyed are characterized by shallow gradients and slow moving water, measurement of this parameter was carried out to provide some indication of the potential of these systems to develop algal blooms. Chlorophyll *a* levels in excess of about 3 ③g/l are considered to be high and one indication of eutrophic conditions.

Mean chlorophyll *a* levels in all of the Rivers were low (Figure 4.7.1). Most values were always below the 3 ③g/l level, but some values exceeding this were observed in the lower reaches of the Canard and Habitant Rivers. The Pereaux River had very low values at all sites (Figure Ax, Appendix II).

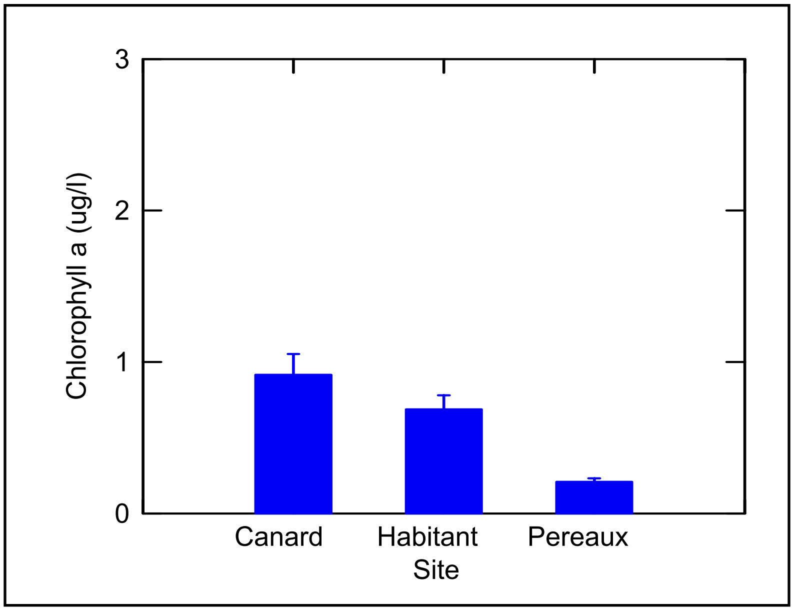

Figure 4.7.1 Mean chlorophyll *a* concentration at each site (error bars are one standard error of the mean).

4.8 Coliform Bacteria

With respect to water quality for agricultural use, the number of coliform bacteria present is the parameter of most interest. This is especially true of fecal coliform bacteria, the presence of which indicates contamination by fecal matter of warm-blooded animals. Guidelines for fecal coliform bacteria levels, as numbers per 100 ml of water, for various water uses are well established and are as follows: drinking water - 0; livestock watering - <50; irrigation of produce for human consumption - <100; contact recreation - <200.

Total coliform bacteria numbers for all samples were always above the level that could be accurately counted (2419 / 100 ml). The numbers of fecal coliform bacteria measured at each sample station are presented in Appendix I. Values ranged from a low of 5 to a high of greater than 2400. The percentage of the number of samples for each site falling within various ranges of fecal coliform numbers is shown in Figure 4.8.1. The percentage of times fecal coliform numbers exceeded 100, the level permissible for irrigation of crops for human consumption, was 67, 52 and 58 for the Pereaux, Habitant and Canard Rivers respectively.

In general, other than lower values during the earlier period of the survey, when precipitation and water levels were high, there was little consistent seasonal variation in fecal coliform.

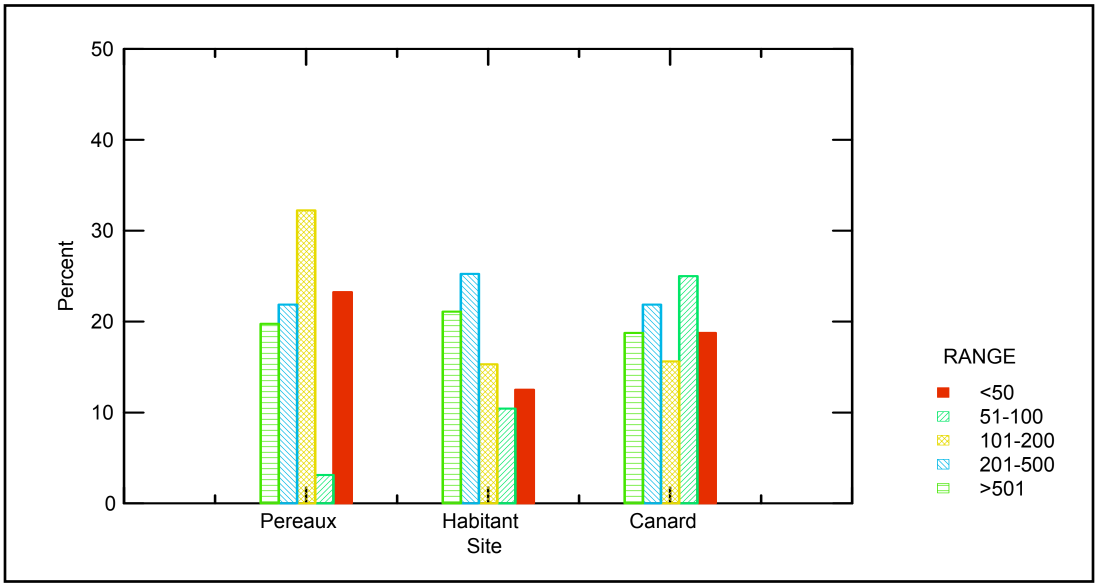

Figure 4.8.1 Percentage of fecal coliform samples in various range categories for each site.

numbers (Figure4.8.2). Although there appeared to be a slight increase in coliform numbers at downstream sites, there was no strong spatial trend at any of the Rivers. Figure 4.8.2 summarizes the percent of samples that fell into various ranges of fecal coliform numbers

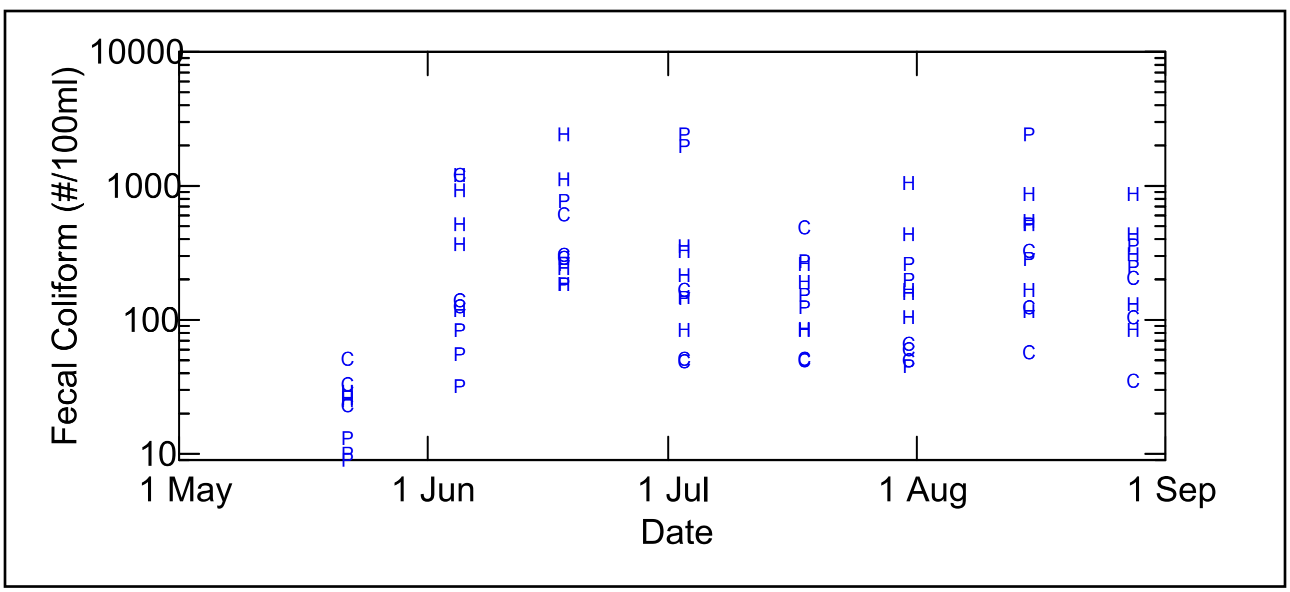

Figure 4.8.1. Seasonal variation in fecal coliform numbers at each site (letters used for symbols indicate site where: C - Canard; H - Habitant; P - Pereaux).

6. References

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6. Appendix I. Database of water quality parameters.

Appendix I Database of water quality parameters.

SITE	Station	Date	Temperature (ºC)	Conductivity (uS/cm)	Total Harness (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	DO Saturation (%)	Total Suspended Matter (mg/l)	Total Suspended Inorganic Matter (mg/l)	Total Suspended Organic Matter (mg/l)	Nitrate (mg N/l)	Total Phosphorus (mg P/l)	Chlorophyll *a* (ug/l)	Fecal Coliforms (#/100 ml)
Canard	C1	21-May	13.8	145	67	50	17	40.6	7.38	9.9	94	4.4	0.0	4.4	1.02	0.24	0.8	51
Canard	C2	21-May	13.8	169	67	46	21	43.4	7.19	10.6	101	4.8	0.4	4.4	1.30	0.25	0.6	33
Canard	C3	21-May	13.9	201	74	53	21	41.8	7.32	8.5	81	6.8	0.4	6.4	2.34	0.52	3.0	23
Canard	C4	21-May	22.5	545	107	73	34	57.6	7.31	7.1	84	42.4	32.4	10.0	1.64	1.02	0.6	4
Canard	C1	4-Jun	16.8	129	59	52	7	39.2	7.07	9.1	93	15.8	10.0	5.8	0.69	0.00	1.4	126
Canard	C2	4-Jun	17.1	154	59	52	7	41.8	7.13	9.4	97	12.2	7.0	5.2	1.16	0.01	0.9	140
Canard	C3	4-Jun	13.4	275	80	71	9	49.8	6.8	6.0	57	28.0	18.0	10.0	1.84	0.06	1.1	1203
Canard	C4	4-Jun	13.6	305	89	67	22	48.4	6.85	5.7	54	157.0	126.5	30.5	2.13	0.33	1.1	1733
Canard	C1	17-Jun	19	162	62	59	3	48	7.09	10.0	108	5.4	2.0	3.4	0.03	0.01	1.2	613
Canard	C2	17-Jun	19.1	192	78	60	18	54	7.32	9.7	105	7.4	3.8	3.6	0.04	0.02	0.6	290
Canard	C3	17-Jun	21.1	313	98	78	20	67.2	7.11	3.5	40	3.0	0.0	3.0	0.04	0.00	0.5	306
Canard	C4	17-Jun	16.9	43600	597	382	215	84.4	7.88	7.5	77	46.5	33.7	12.8	0.07	0.09	1.4	17
Canard	C1	2-Jul	20.5	177	55	55	0	49.8	8.3	13.6	153	4.2	1.6	2.6	0.72	0.32	0.6	49
Canard	C2	2-Jul	19.3	196	75	62	13	104.4	8.35	12.5	136	3.8	1.0	2.8	0.80	0.45	0.3	167
Canard	C3	2-Jul	19.2	298	86	79	7	67.8	7.21	7.0	76	3.0	0.0	3.0	0.76	0.67	0.7	51
Canard	C4	2-Jul	16.5	44900	1237	1066	171	112	7.97	7.4	76	243.2	186.4	56.8	0.10	1.19	2.0	365
Canard	C1	17-Jul	19.9	169	48	48	0	45.2	7.22	12.5	138	3.8	0.7	3.0	0.87	0.26	1.1	51
Canard	C2	17-Jul	19.3	190	64	59	5	48	7.3	10.8	118	2.8	0.0	2.8	0.97	0.20	0.4	488
Canard	C3	17-Jul	19.3	312	81	71	10	70.6	7.26	6.8	74	3.8	1.2	2.6	1.61	0.63	0.7	50
Canard	C4	17-Jul	20.7	78500					7.7	6.7	76	35.7	25.3	10.3	0.83	0.89	0.6	435

SITE	Station	Date	Temperature (ºC)	Conductivity (uS/cm)	Total Harness (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	DO Saturation (%)	Total Suspended Matter (mg/l)	Total Suspended Inorganic Matter (mg/l)	Total Suspended Organic Matter (mg/l)	Nitrate (mg N/l)	Total Phosphorus (mg P/l)	Chlorophyll *a* (ug/l)	Fecal Coliforms (#/100 ml)
Canard	C1	30-Jul	20.7	182	59	59	0	41	7.79	11.8	133	11.8	9.0	2.8	1.00	0.44	1.7	60
Canard	C2	30-Jul	20.5	202	70	64	6	52.2	7.54	8.4	95	6.8	6.6	0.2	1.12	0.32	0.4	66
Canard	C3	30-Jul	18.9	301	90	71	19	66.8	7.43	6.6	71	5.4	4.0	1.4	1.21	0.52	2.1	50
Canard	C4	30-Jul	18.6	43000	2280	541	1739	101.2	7.87	7.0	75	79.6	63.2	16.4	0.47	1.08	0.9	1986
Canard	C1	14-Aug	18.3	211	78	59	19	48.2	7.49	7.5	80	4.0	2.6	1.4	2.05	0.58	0.7	124
Canard	C2	14-Aug	18.7	217	72	70	2	56.4	7.48	7.9	85	4.2	3.4	0.8	1.35	0.37	0.3	326
Canard	C3	14-Aug	19.5	434	99	81	18	85	7.63	3.0	33	2.4	1.8	0.6	1.96	0.99	0.5	57
Canard	C4	14-Aug	20.4	45700				113.4	7.78	6.3	71	46.6	32.0	14.6	0.04	0.39	1.5	2419
Canard	C1	27-Aug	18.9	205	68	66	2	50	7.11	7.0	75	16.2	13.6	2.6	1.26	0.49	1.7	35
Canard	C2	27-Aug	18.4	200	72	62	10	52.4	7.12	7.3	78	3.6	3.4	0.2	0.91	0.33	0.2	104
Canard	C3	27-Aug	18.8	390	90	79	11	80.6	7.02	2.9	31	2.4	1.8	0.6	1.23	0.94	0.4	206
Canard	C4	27-Aug	19	12000		432		96	7.65	7.6	.	126.9	98.5	28.4	0.28	1.51	7.7	2419
Habitant	H1	21-May	11.8	169	74	63	11	49.6	7.2	10.2	93	16.8	10.0	6.8	1.15	0.24	0.9	29
Habitant	H2	21-May	13.2	187	81	76	5	62	7.14	9.6	91	6.8	0.8	6.0	1.30	0.24	3.2	29
Habitant	H3	21-May	13.7	201	85	75	10	49.8	7.25	10.1	97	5.6	0.8	4.8	1.05	0.19	0.3	26
Habitant	H4	21-May	14.7	257	115	94	21	55.2	7.27	9.9	96	6.4	1.6	4.8	2.15	0.26	0.5	26
Habitant	H5	21-May	15.4	262	118	96	22	55	7.35	10.1	100	4.8	0.0	4.8	2.16	0.27	0.2	25
Habitant	H1	4-Jun	14.5	192	86	71	15	57.6	7.05	8.9	86	13.2	8.0	5.2	1.09	0.01	0.3	118
Habitant	H2	4-Jun	14.4	182	82	78	4	61	7.16	7.6	74	5.8	1.8	4.0	0.59	0.00	0.8	1203
Habitant	H3	4-Jun	13.6	191	85	82	3	52.6	7.13	8.7	83	10.6	5.6	5.0	1.11	0.01	0.6	921
Habitant	H4	4-Jun	13.6	246	115	100	15	68	7.07	8.6	82	12.8	7.4	5.4	1.83	0.02	0.4	517
Habitant	H5	4-Jun	12.3	252	110	100	10	56.4	7.17	8.2	75	16.2	10.2	6.0	1.17	0.01	0.4	365
Habitant	H6	4-Jun	14	271	111	107	4	57.2	7.05	7.7	74	13.8	8.2	5.6	1.78	0.01	0.5	1414

SITE	Station	Date	Temperature (ºC)	Conductivity (uS/cm)	Total Harness (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	DO Saturation (%)	Total Suspended Matter (mg/l)	Total Suspended Inorganic Matter (mg/l)	Total Suspended Organic Matter (mg/l)	Nitrate (mg N/l)	Total Phosphorus (mg P/l)	Chlorophyll *a* (ug/l)	Fecal Coliforms (#/100 ml)
Habitant	H1	17-Jun	14.5	263	120	101	19	100.2	7.57	8.3	81	27.8	17.0	10.8	0.02	0.04	0.9	2419
Habitant	H2	17-Jun	16.6	261	116	110	6	68.2	7.5	10.8	110	6.6	2.2	4.4	0.18	0.00	0.7	1119
Habitant	H3	17-Jun	17.9	288	133	118	15	77.8	7.49	8.6	90	4.5	1.1	3.4	0.05	0.00	0.5	290
Habitant	H4	17-Jun	18.1	413	162	162	0	83.8	7.7	9.2	97	7.4	3.0	4.4	1.21	0.02	1.1	241
Habitant	H5	17-Jun	18.3	407	184	159	25	85.4	7.73	7.5	79	5.8	2.4	3.4	0.20	0.00	1.2	185
Habitant	H6	17-Jun	21.6	457	174	150	24	86.2	7.65	9.3	107	7.0	0.4	6.6	2.97	0.00	1.3	140
Habitant	H1	2-Jul	13.2	316	128	120	8	113.6	8.01	8.8	83	4.8	1.4	3.4	1.96	0.21	0.2	325
Habitant	H2	2-Jul	17.4	291	138	124	14	95.4	8.45	17.9	186	6.2	2.2	4.0	2.25	0.23	0.7	84
Habitant	H3	2-Jul	18.6	348	146	136	10	88	7.64	8.7	93	4.0	0.0	4.0	2.13	0.14	0.3	214
Habitant	H4	2-Jul	19	480	203	199	4	95	8.11	11.7	126	3.4	1.0	2.4	3.55	0.23	0.3	355
Habitant	H5	2-Jul	18.3	475	217	191	26	92.4	7.84	13.1	140	6.0	3.6	2.4	2.85	0.20	0.2	148
Habitant	H6	2-Jul	20.1	550	202	140	62	94.2	7.98	10.0	111	11.6	6.0	5.6	2.25	0.41	2.7	7
Habitant	H1	17-Jul	13.2	318	133	120	13	95.8	7.51	9.3	87	2.9	0.6	2.3	2.01	0.11	0.1	192
Habitant	H2	17-Jul	16.8	298	136	120	16	94.8	8	13.9	142	3.4	0.8	2.6	3.21	0.14	0.7	84
Habitant	H3	17-Jul	17.8	356	159	143	16	92.8	7.57	8.8	92	7.0	2.6	4.3	2.52	0.10	0.4	261
Habitant	H4	17-Jul	18.2	476	215	215	0	95.2	8.16	17.5	185	2.8	0.4	2.4	3.64	0.10	0.9	84
Habitant	H5	17-Jul	17.6	481	215	202	13	96.8	7.93	11.9	124	2.4	0.4	2.0	3.19	0.05	0.3	86
Habitant	H6	17-Jul	21.7	515	196	172	24	80.6	7.45	12.2	142	2.6	0.0	2.6	2.79	0.20	1.0	0
Habitant	H1	30-Jul	13.3	323	162	149	13	99	7.86	8.2	78	1.8	1.2	0.6	1.80	0.18	0.1	1046
Habitant	H2	30-Jul	18.8	295	129	112	17	90	8.09	12.9	138	2.6	2.0	0.6	3.16	0.22	0.8	104
Habitant	H3	30-Jul	18.6	353	149	137	12	96.2	7.83	9.0	96	3.6	2.4	1.2	2.78	0.11	0.3	435
Habitant	H4	30-Jul	19.1	504	229	210	19	97.8	8.74	16.9	183	1.8	1.4	0.4	6.52	0.15	0.7	167
Habitant	H5	30-Jul	18	521	232	213	19	98.8	8.09	11.7	123	3.4	2.8	0.6	4.84	0.06	0.7	158

SITE	Station	Date	Temperature (ºC)	Conductivity (uS/cm)	Total Harness (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	DO Saturation (%)	Total Suspended Matter (mg/l)	Total Suspended Inorganic Matter (mg/l)	Total Suspended Organic Matter (mg/l)	Nitrate (mg N/l)	Total Phosphorus (mg P/l)	Chlorophyll *a* (ug/l)	Fecal Coliforms (#/100 ml)
Habitant	H6	30-Jul	21.1	558	201	186	15	94.4	8.25	10.9	124	2.8	1.0	1.8	3.37	0.09	1.0	5
Habitant	H1	14-Aug	12.9	308	127	119	8	97.6	7.79	9.3	87	1.8	1.2	0.6	1.78	0.18	0.2	517
Habitant	H2	14-Aug	16.9	308	138	121	17	97.4	7.56	10.4	106	5.0	5.0	0.0	3.75	0.20	1.3	115
Habitant	H3	14-Aug	18.1	359	155	144	11	103	7.77	8.5	89	3.0	2.2	0.8	3.50	0.16	0.8	866
Habitant	H4	14-Aug	17.8	525	232	223	9	102.2	7.95	11.7	122	2.2	1.2	1.0	6.16	0.26	1.8	548
Habitant	H5	14-Aug	17.3	532	235	213	22	106	7.71	9.3	96	1.6	1.4	0.2	5.04	0.19	0.6	167
Habitant	H6	14-Aug	21.8	570	211	180	31	86.2	7.65	11.3	132	2.6	1.0	1.6	2.86	0.30	0.8	276
Habitant	H1	27-Aug	12.9	495	152	129	23	99.8	7.76	9.3	87	0.8	0.8	0.0	1.67	0.10	0.1	308
Habitant	H2	27-Aug	15.6	312	138	132	6	95.6	7.52	9.9	98	3.2	2.2	1.0	3.93	0.17	0.5	84
Habitant	H3	27-Aug	17.4	358	156	133	23	104.6	7.54	8.8	91	1.9	1.4	0.5	3.01	0.13	1.2	866
Habitant	H4	27-Aug	18.7	505	236	221	15	103.8	8.01	13.0	139	5.2	4.0	1.2	5.18	0.26	1.8	435
Habitant	H5	27-Aug	16.7	510	229	229	0	107.4	7.68	7.4	76	2.4	2.0	0.4	4.02	0.21	0.4	131
Habitant	H6	27-Aug	20.7	507	202	184	18	85.4	8.03	11.5	130	5.2	1.9	3.3	2.65	0.22	0.7	6
Pereaux	P1	21-May	19.8	211							86							10
Pereaux	P2	21-May	15	334	128	108	20	72.2	7.69	10.1	.	2.4	0.0	2.4	2.58	0.13	0.3	13
Pereaux	P3	21-May	15.4	336	131	113	18	74.6	7.67	10.3	99	11.6	7.2	4.4	3.05	0.14	0.3	9
Pereaux	P4	21-May	16.5	455	146	118	28	29.6	7.7	10.9	102	82.2	63.8	18.4	2.15	0.13	0.2	3
Pereaux	P2	22-May	9.7	193	60			27.6	7.12	9.9	111							
Pereaux	P1	4-Jun									.							32
Pereaux	P2	4-Jun	11.2	323	133	121	12	69.8	7.33	9.6	86	5.6	0.8	4.8	2.47	0.00	0.3	55
Pereaux	P3	4-Jun	11.3	319	127	111	16	70	7.36	9.7	88	6.0	1.6	4.4	2.27	0.00	0.3	83
Pereaux	P4	4-Jun	11.3	4500	138	118	20	66.2	7.33	10.1	91	6.4	1.6	4.8	2.56	0.00	0.2	152
Pereaux	P1	17-Jun									.							184

SITE	Station	Date	Temperature (ºC)	Conductivity (uS/cm)	Total Harness (mg/l)	Calcium Hardness (mg/l)	Magnesium Hardness (mg/l)	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	DO Saturation (%)	Total Suspended Matter (mg/l)	Total Suspended Inorganic Matter (mg/l)	Total Suspended Organic Matter (mg/l)	Nitrate (mg N/l)	Total Phosphorus (mg P/l)	Chlorophyll *a* (ug/l)	Fecal Coliforms (#/100 ml)
Pereaux	P2	17-Jun	11.3	404	175	140	35	96.2	7.69	9.9	89	9.8	5.0	4.8	1.10	0.02	0.3	261
Pereaux	P3	17-Jun	11.6	395	179	148	31	98	7.66	9.7	89	11.0	6.2	4.8	3.03	0.00	0.4	770
Pereaux	P4	17-Jun	12.8	562	181	152	29	100	7.88	10.1	95	8.6	4.2	4.4	0.91	0.00	0.4	192
Pereaux	P1	2-Jul									.							2419
Pereaux	P2	2-Jul	11	449	180	155	25	106	7.86	10.9	98	7.8	3.0	4.8	3.55	0.10	0.1	146
Pereaux	P3	2-Jul	11.8	439	178	164	14	107	7.83	10.7	98	11.8	6.8	5.0	3.68	0.10	0.2	1986
Pereaux	P4	2-Jul	13.6	29300	287	287	0	108.8	7.85	11.3	107	5.0	1.8	3.2	3.50	0.44	5.6	264
Pereaux	P1	17-Jul									.							124
Pereaux	P2	17-Jul	11.2	441	177	168	9	107.6	7.8	10.4	94	3.6	1.0	2.6	5.35	0.10	0.1	153
Pereaux	P3	17-Jul	12.3	438	173	165	8	108	7.99	10.4	96	14.2	10.0	4.2	5.59	0.14	0.2	272
Pereaux	P4	17-Jul	13.8	821	229	214	15	111.2	8.23	11.0	105	7.8	4.2	3.6	4.47	0.14	0.2	299
Pereaux	P1	30-Jul									.							45
Pereaux	P2	30-Jul	12	448	185	162	23	108.6	7.99	10.3	95	1.8	0.8	1.0	5.42	0.24	0.1	199
Pereaux	P3	30-Jul	12.7	445	172	160	12	109	8.02	10.4	97	2.6	2.6	0.0	2.84	0.09	0.2	261
Pereaux	P4	30-Jul	14.5	1478	261	220	41	110.4	8.12	10.5	102	4.8	4.0	0.8	3.81	0.14	1.9	156
Pereaux	P1	14-Aug									.							2419
Pereaux	P2	14-Aug	11.3	451	188	168	20	111.6	7.87	10.5	95	3.2	2.4	0.8	5.55	0.13	0.1	285
Pereaux	P3	14-Aug	11.2	448	174	161	13	108.4	7.8	10.4	94	4.4	4.0	0.4	4.24	0.12	0.2	517
Pereaux	P4	14-Aug	14.7	32300		171		111.6	7.77	10.4	101	1.8	1.4	0.4	4.09	0.16	0.1	2419
Pereaux	P1	27-Aug									.							
Pereaux	P2	27-Aug	11.9	450	181	166	15	110.4	7.9	10.2	94	4.0	3.2	0.9	6.18	0.14	0.1	248
Pereaux	P3	27-Aug	13	445	179	170	9	110.2	7.97	10.1	95	6.4	5.6	0.8	6.58	0.15	0.2	360
Pereaux	P4	27-Aug	13.7	900	240	195	45	112	8.08	11.7	111	5.3	5.1	0.2	5.28	0.15	0.1	116

7. Appendix II Time series plot of water quality parameters.

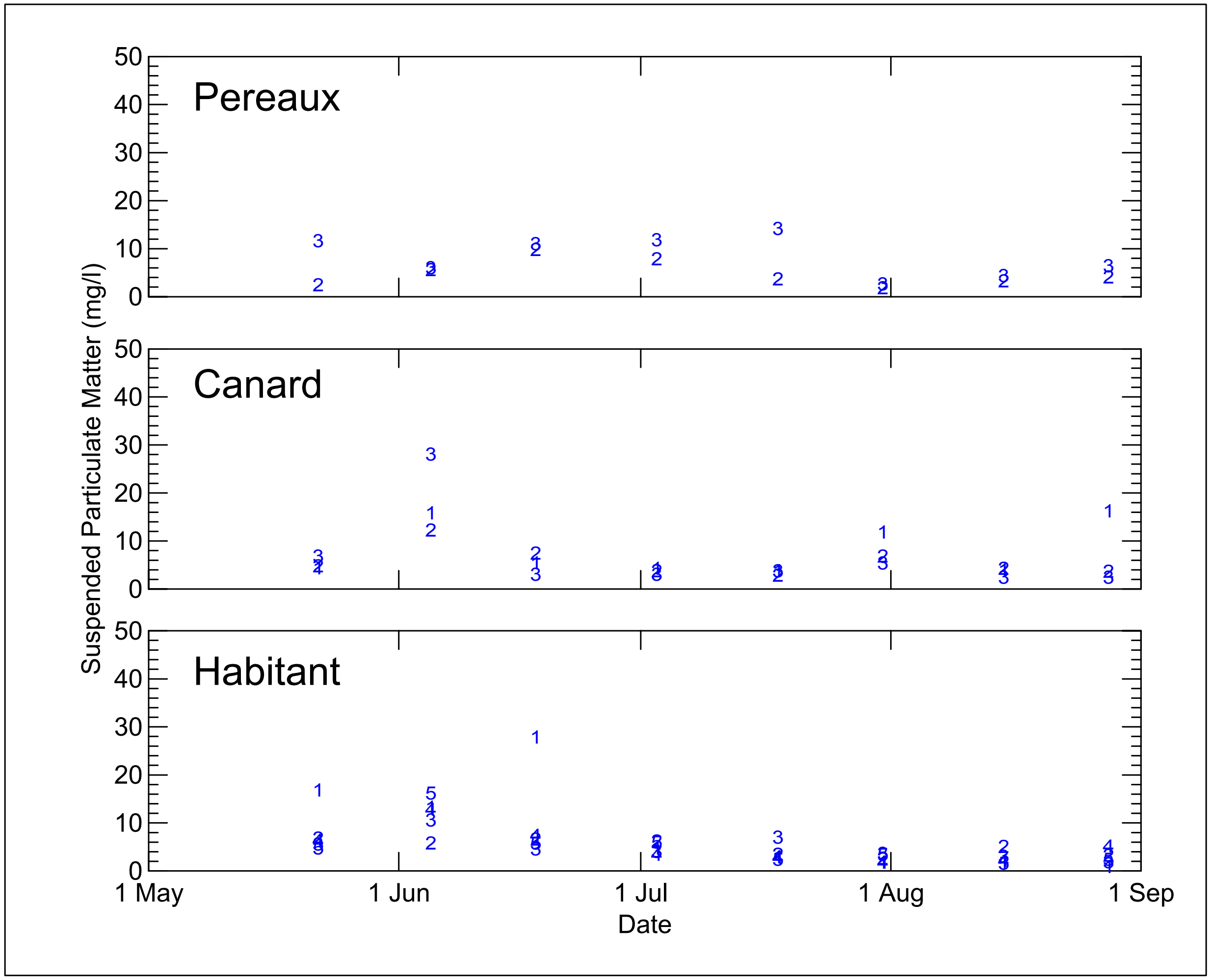

Figure 1A. Seasonal variation in total suspended particulate matter (numbers used for symbols refer to location of sample (see text Figure 2.1).

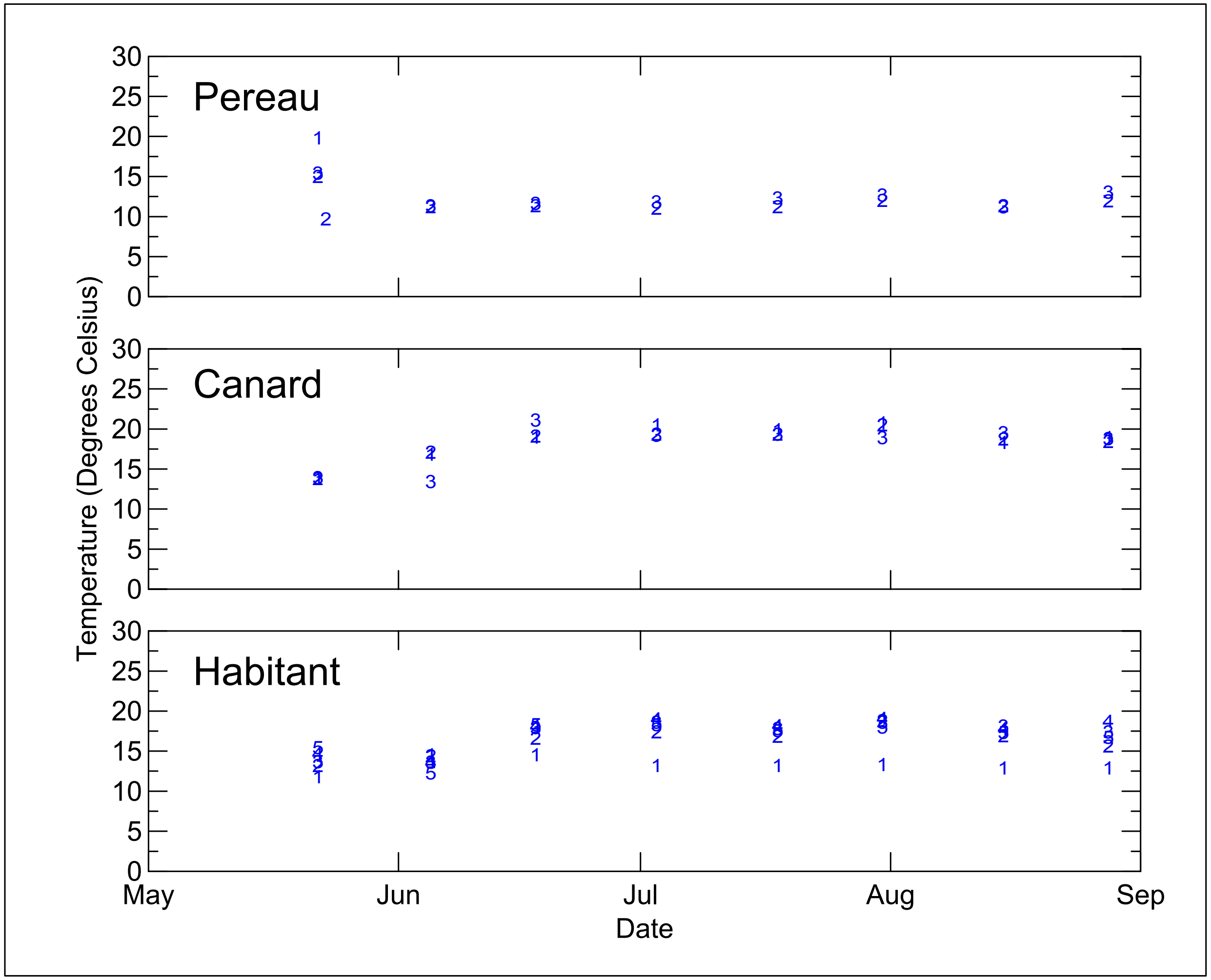

Figure 2A. Seasonal variation in water temperature (numbers used for symbols refer to location of sample (see text Figure 2.1).

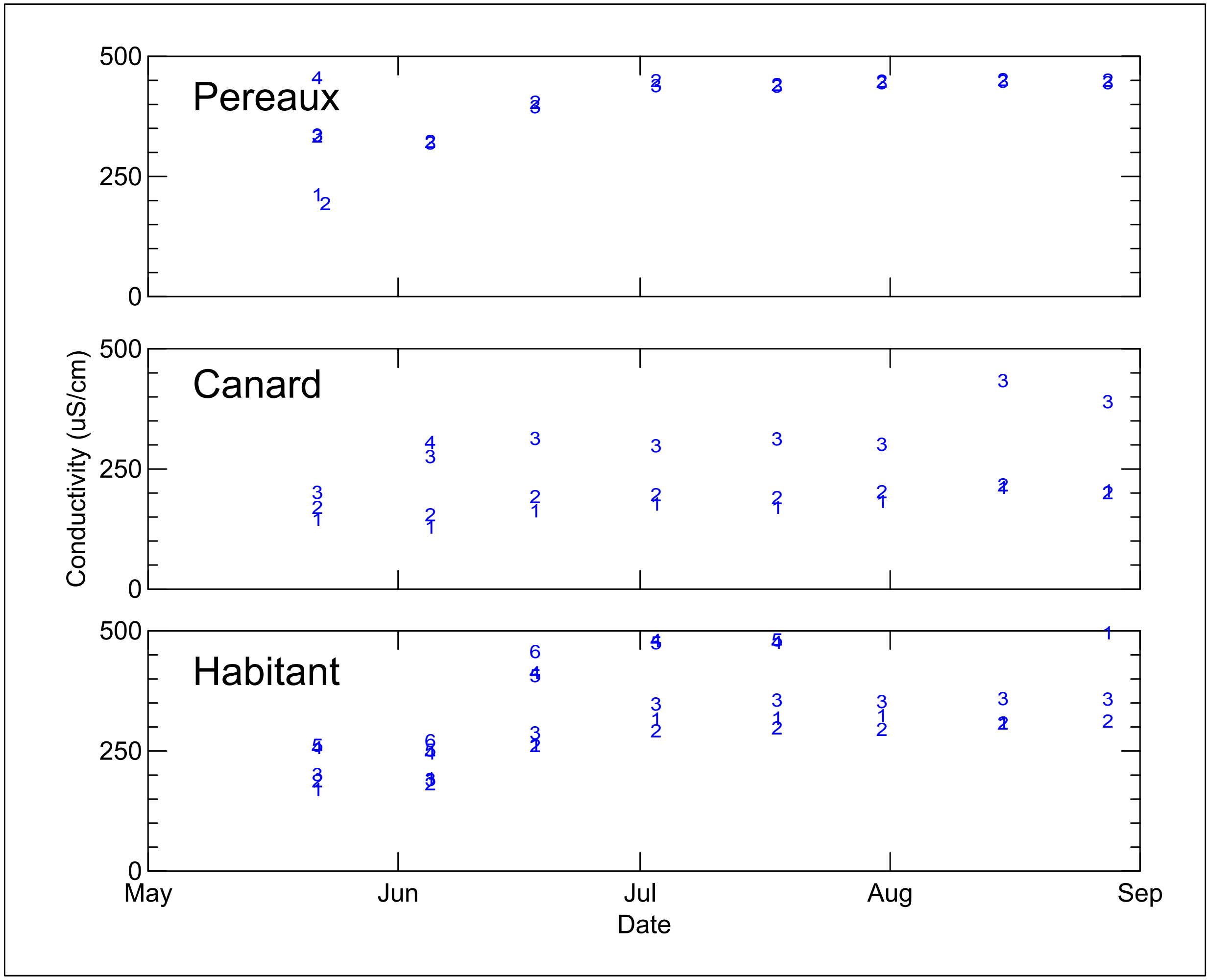

Figure 3A. Seasonal variation in conductivity (numbers used for symbols refer to location of sample (see text Figure 2.1).

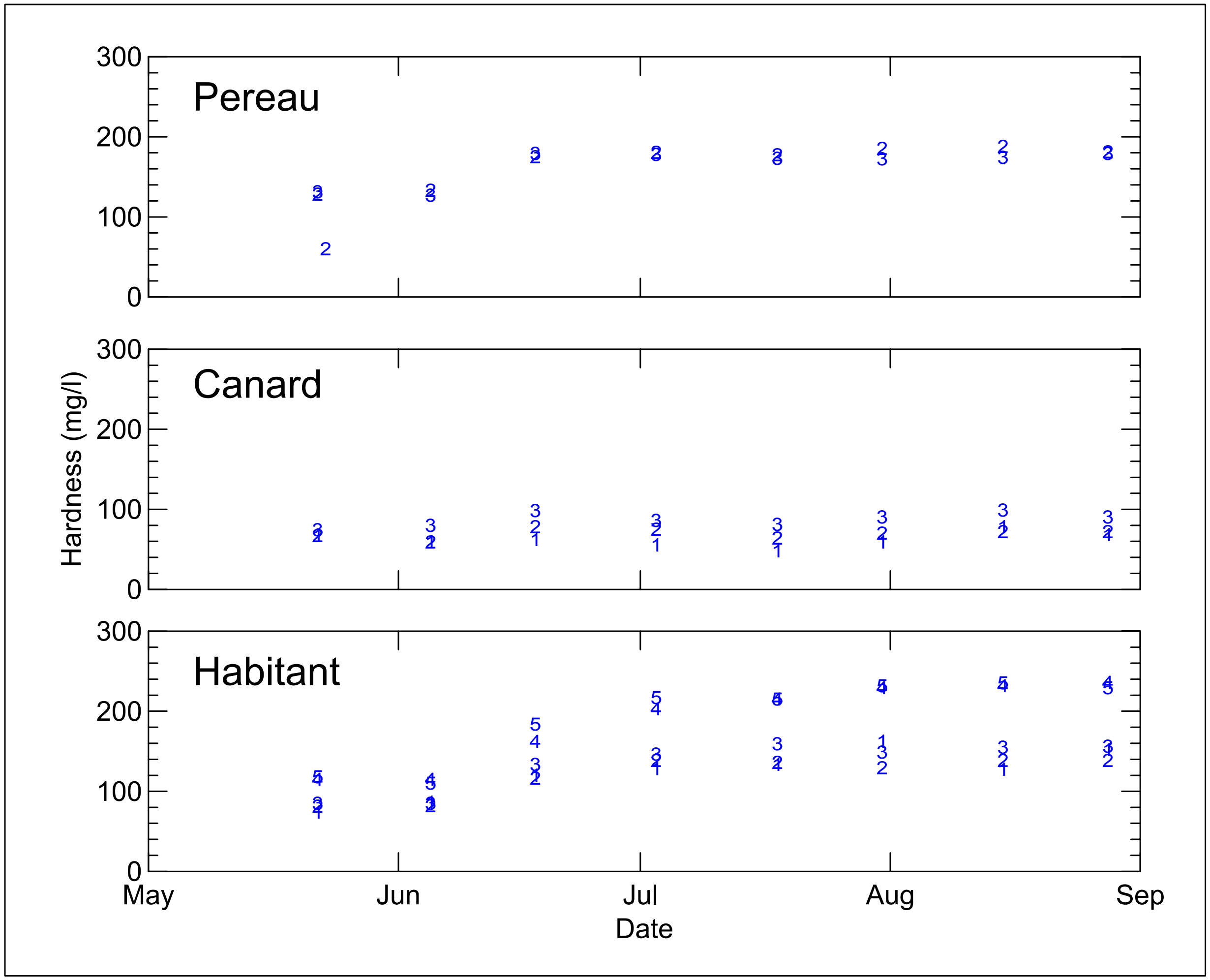

Figure 4A. Seasonal variation in total hardness (numbers used for symbols refer to location of sample (see text Figure 2.1).

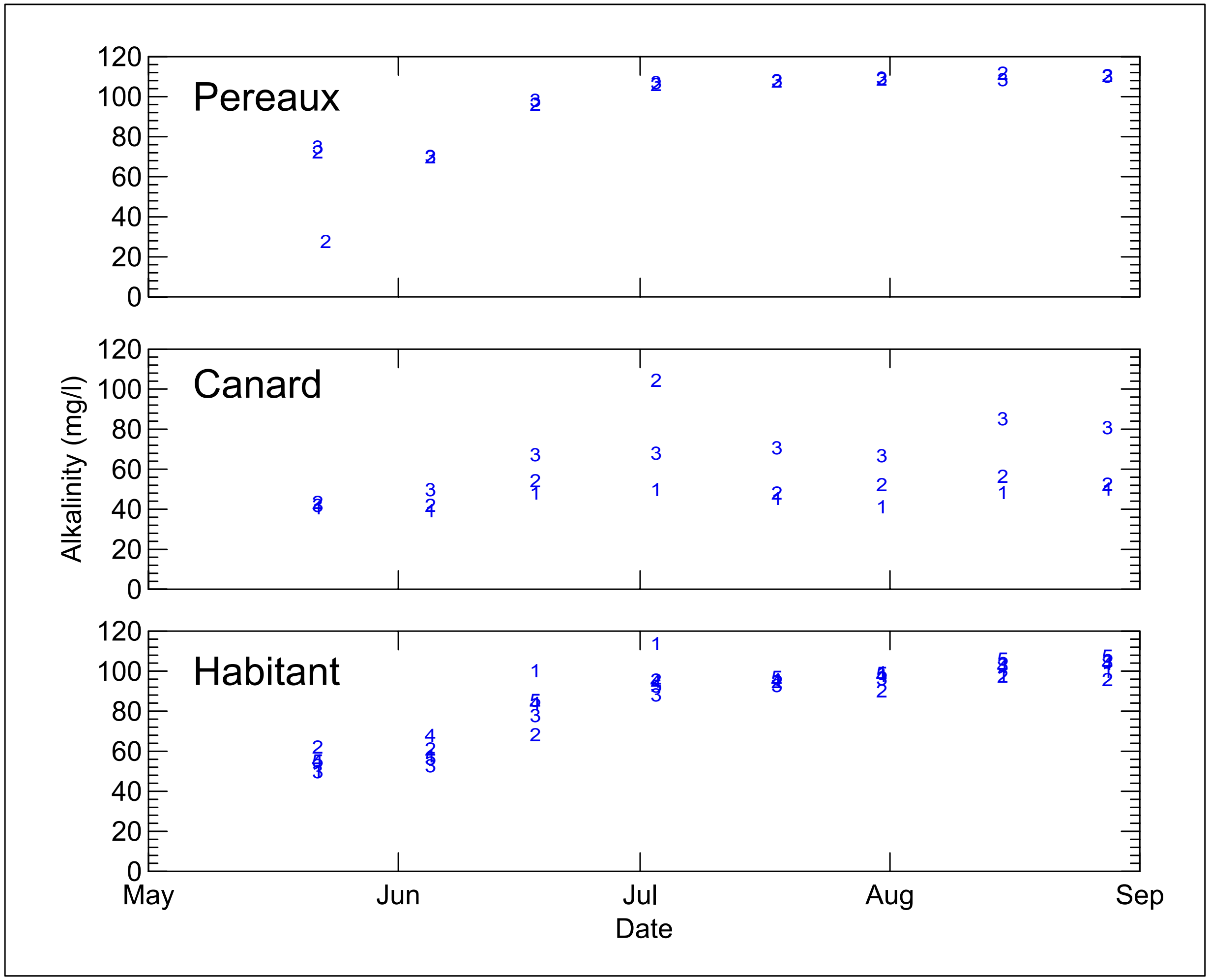

Figure 5A. Seasonal variation in alkalinity (numbers used for symbols refer to location of sample (see text Figure 2.1).

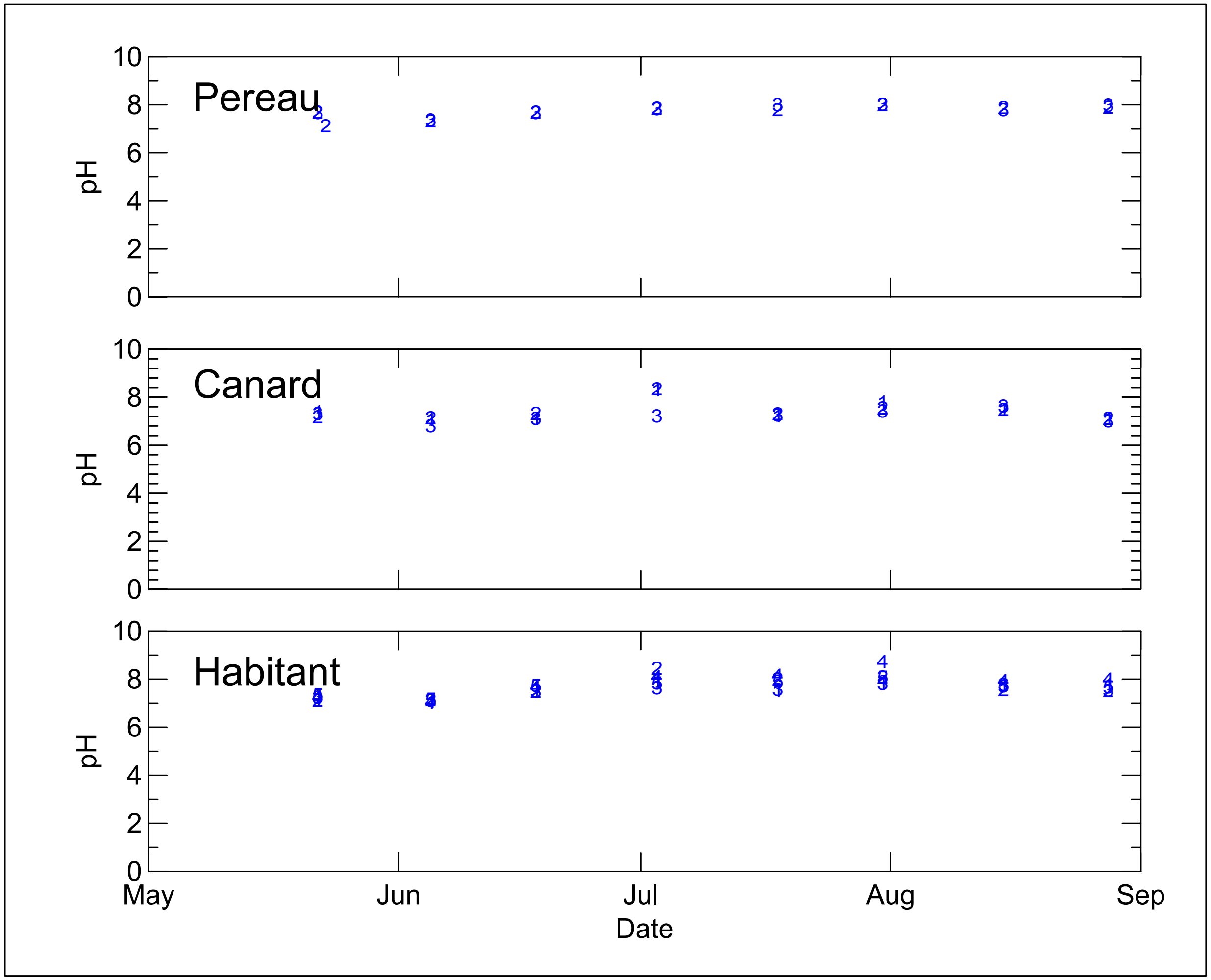

Figure 6A. Seasonal variation in pH (numbers used for symbols refer to location of sample (see text Figure 2.1).

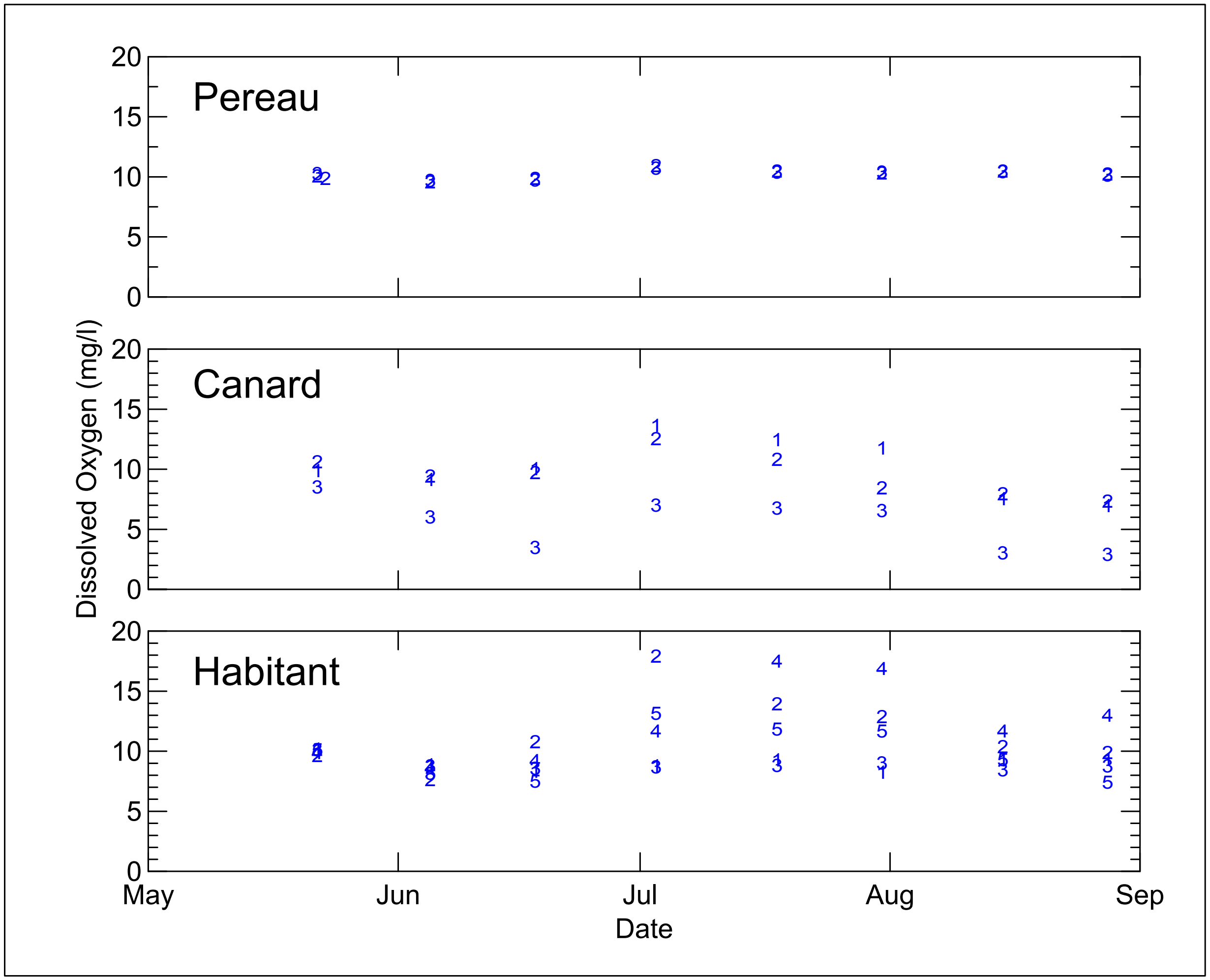

Figure 7A. Seasonal variation in dissolved oxygen (numbers used for symbols refer to location of sample (see text Figure 2.1).

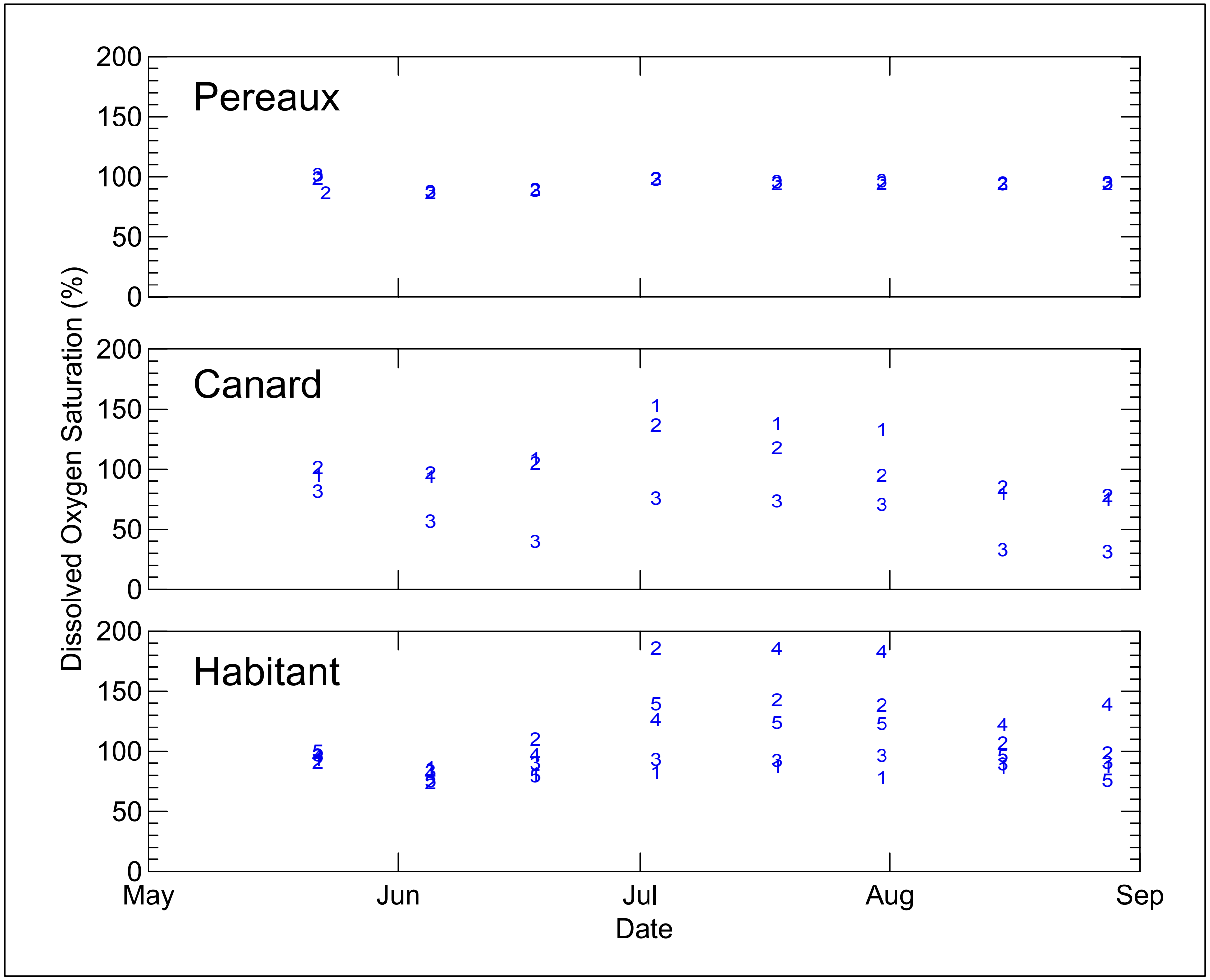

Figure 8A. Seasonal variation in percent dissolved oxygen saturation (numbers used for symbols refer to location of sample (see text Figure 2.1).

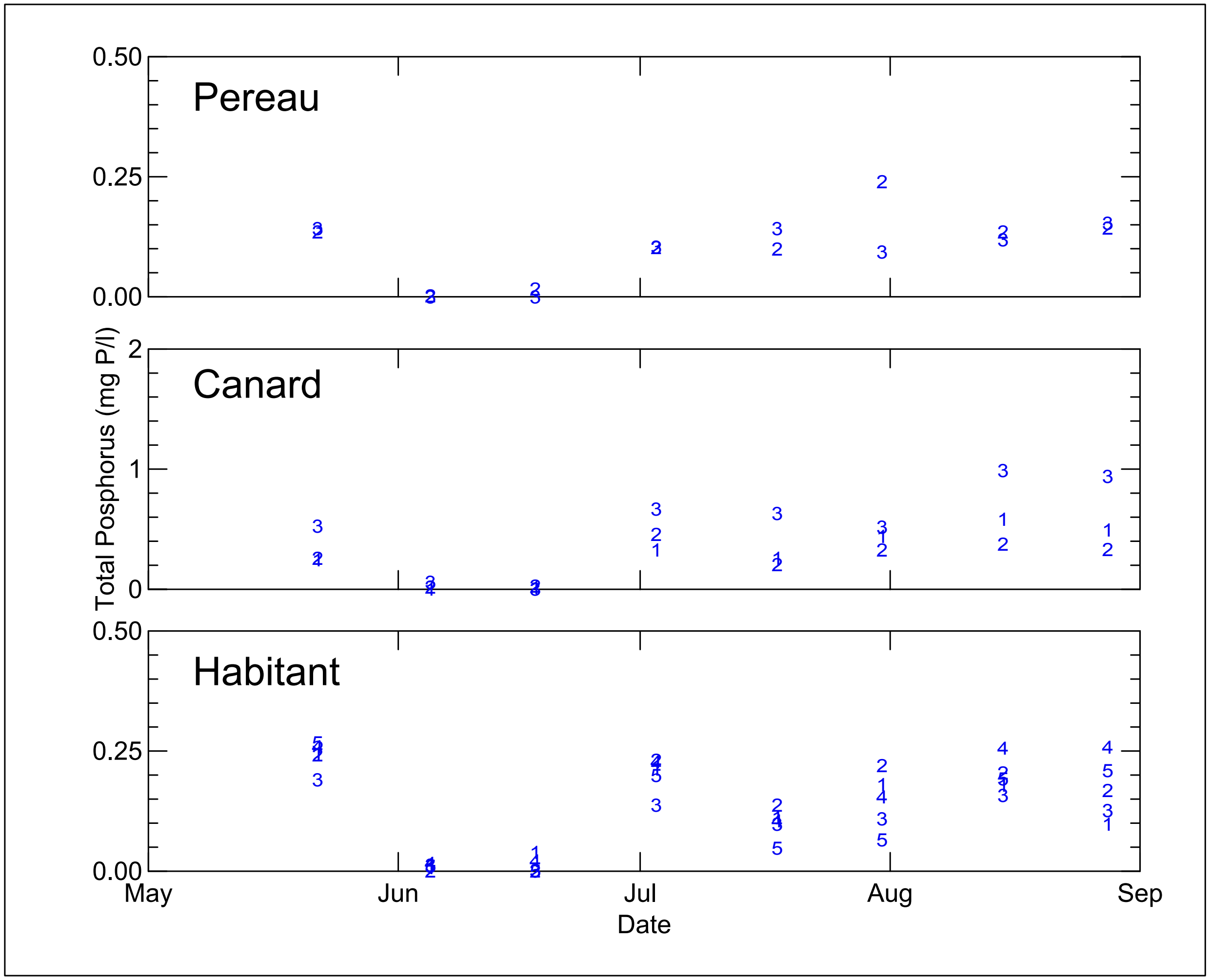

Figure 9A. Seasonal variation in total phosphorus (numbers used for symbols refer to location of sample (see text Figure 2.1).

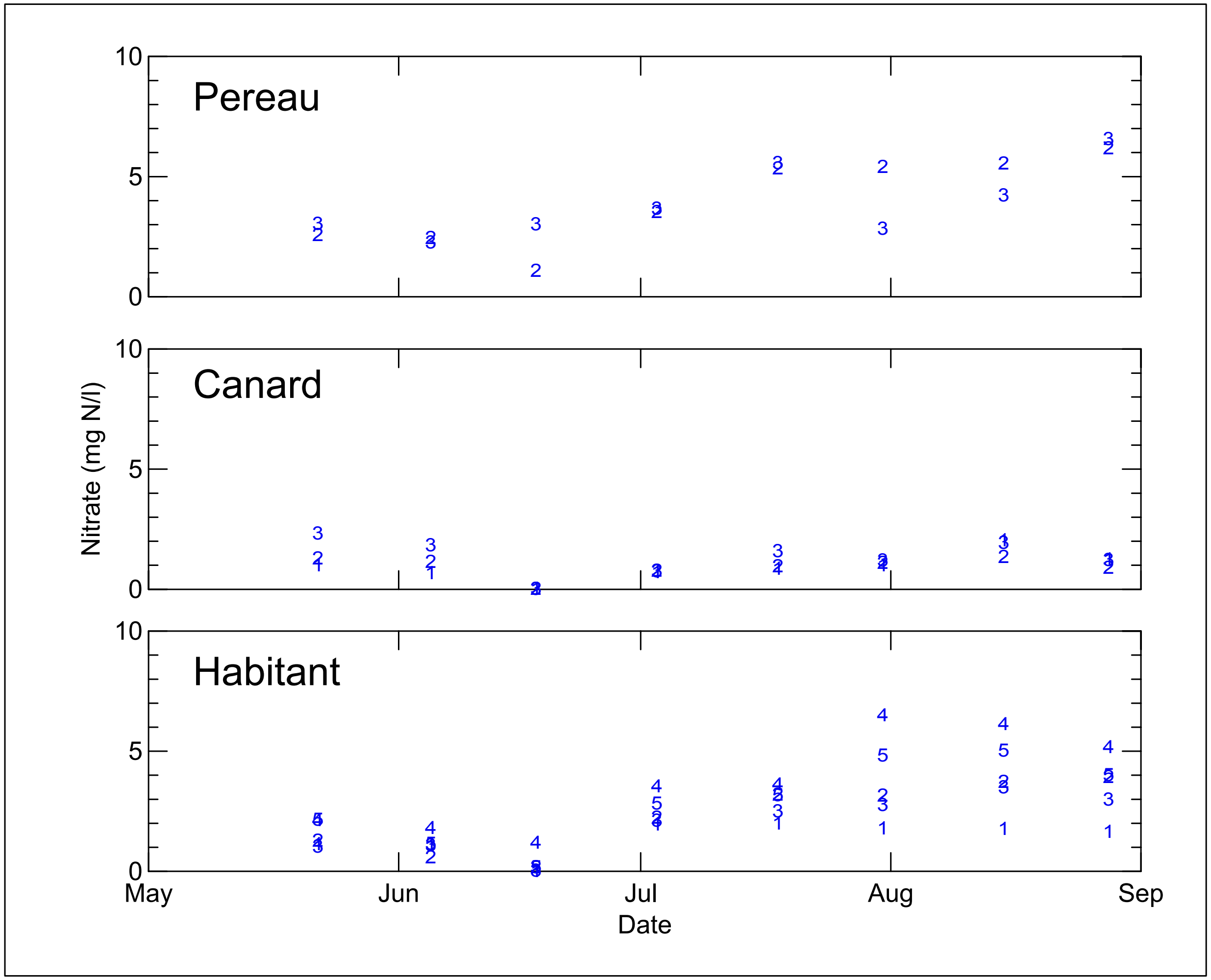

Figure 10A. Seasonal variation in nitrate (numbers used for symbols refer to location of sample (see text Figure 2.1).

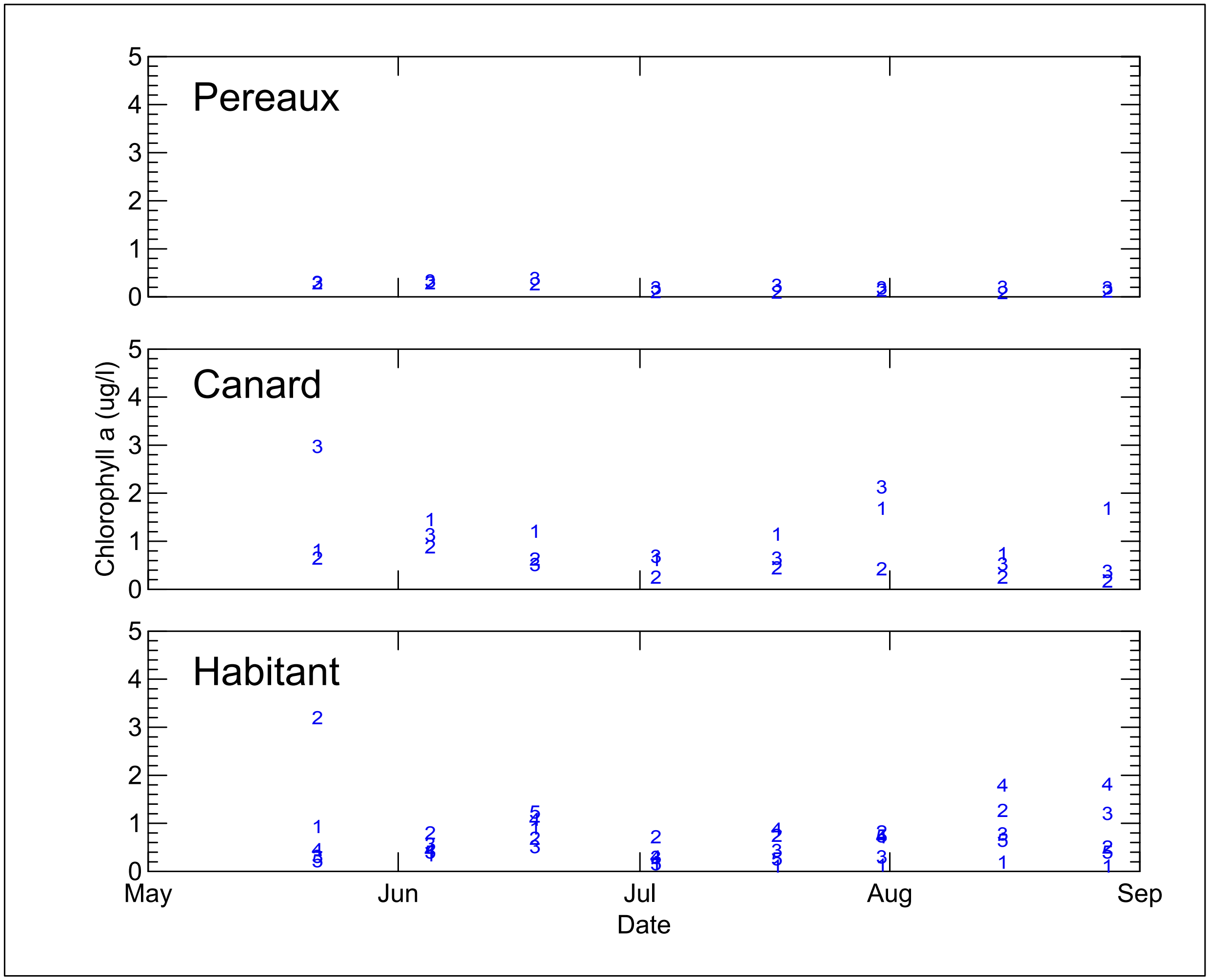

Figure 11A. Seasonal variation in chlorophyll *a* (numbers used for symbols refer to location of sample (see text Figure 2.1).