EMRAS Tritium/C14 Working Group

The Dynamic Perch Lake Mussel Transplantation Scenario Description

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1. BACKGROUND INFORMATION

Tritium can represent a key radionuclide in the aquatic environment, potentially contributing significantly to the doses received by aquatic non-human biota in surface waters receiving tritium inputs. Although in many cases, steady state models represent practical tools to estimate free-water tritium exposures (and to a lesser extent, OBT exposures), aquatic organisms are occasionally exposed to short-term, elevated tritium concentrations in water when tritium is released accidentally to aquatic systems. Depending upon the nature and the duration of such events, in some cases, steady state models may or may not be predictive of true organism exposure conditions.

In general, the rates of HTO uptake and OBT formation are not well known under dynamic exposure conditions, but can be studied by transplanting biomonitoring species, such as freshwater mussels, from areas with background tritium concentrations to those with measurable tritium levels. In this way, changes in HTO and OBT concentrations can be monitored to quantify their responses to dynamic exposure conditions.

1.1 Study Objective

The objective of this study was to quantify the rates of HTO uptake and OBT formation in freshwater mussels (*Elliptio complanata*) receiving abrupt increases in their tritium exposure levels through transplantation from areas with background tritium concentrations to Perch Lake, a small, Canadian Shield lake receiving chronic, low-level tritium inputs. This information forms the basis of a model-data validation scenario for tritium uptake under dynamic exposure conditions. Perch Lake was studied in an earlier EMRAS scenario that was designed for model-data validation of steady state HTO and OBT models for a range of freshwater receptor species.

2. SITE DESCRIPTION

Located on the site of Chalk River Laboratories (CRL), Perch Lake contains trace amounts of tritium (Figures 1 and 2). The lake receives tritium inputs via groundwater that is migrating through an extensive sand aquifer from a waste management area (WMA) located approximately 750 m to the north of the lake. The WMA was in operation for approximately 40 years until it was shut down in 1999. The tritium forms a well-defined underground plume that is narrow near the source, but broadens to a width of approximately 1,000 m by the time it reaches the lake. Tritium, in the form of HTO, discharges into the lake through the sediments from below and also through the Inlet 2 inflowing stream (Figure 2), which flows above the underground plume. Inlet 1 also shows slightly elevated levels of tritium; however, inflowing streams at Inlets 3, 4 and 5 are all uncontaminated. The rate and distribution of HTO releases to the lake are not known quantitatively, although it is believed that the lake is

well-mixed in the vicinity of the mussel transplantation cages, which were deployed near the outflowing stream in the lake.

In terms of its physical size, Perch Lake is a small, shallow freshwater Canadian Shield lake, with a maximum fetch of approximately 800 m, a surface area of 4.5 x 10^5 m^2 and a volume of 9.1 x 10^5 m^3. The mean depth of the lake is 2.0 m and the maximum depth is 4.1 m. The lake drains a watershed of area 5.65 x 10^6 m^2 and the residence time of water in the lake is approximately 0.5 years. Perch Lake can be considered unstratified, although there is weak stratification in deeper areas in the summer, when surface waters are approximately 5 ^oC higher than those at lake bottom. The lake is typically ice-covered from early December to mid-April. Based on historical measurements, mean monthly water temperatures are 13, 19, 24, 23, 19 and 11^o C for the months of May through October, respectively. Surface water temperatures measured in the vicinity of the mussel transplantation cages in Perch Lake over the course of this study are provided in Table 1 and Figure 3. These values correlate well with air temperatures taken over the same time period.

Sediments in the lake are composed of sand and gyttja (decomposing organic material). The mean dry bulk density is approximately 185 kg m^{-3}, but values vary substantially across the lake depending on local composition. The sediments in the vicinity of the mussel transplantation cages are primarily sandy in nature, with some accumulation of organic matter. These sediments consist of approximately 50% water by weight and the sedimentation rate is 0.16 kg m^{-2} a^{-1} or 0.06 cm a^{-1}.

3. STUDY DESIGN

Two pairs of mussel transplantation cages were built and deployed in Perch Lake in early July 2004. These cages contained freshwater mussels originating from a site with background tritium concentrations (as described in Section 3.3.1 below and as shown in Figure 1) to quantify rates of temporal changes in HTO and OBT in mussel soft tissues. In doing so, two sets of exposure conditions were established, as summarized in Table 2. These included exposure to tritium via the surface water pathway only (Cages 1 and 2), and exposure via both surface sediments and surface water (Cages 3 and 4). A more detailed description of each cage set-up is provided in Sections 3.3.2 and 3.3.3 below.

3.1 Cage Design

Each mussel transplantation cage was constructed with an 8 x 8 design, resulting in a total of 64 compartments per cage. Each compartment was assigned a unique alphanumeric code (as shown in Table 3) and one animal was placed into each compartment to facilitate tracking of each animal. Cages were constructed with 2 x 2 cedar and chicken wire, with dimensions of 96 cm (length) x 96 cm (width) x 12 cm (height). Individual cage compartments had surface area dimensions of 12 cm x 12 cm.

3.2 Selection of Animals

Freshwater mussels (*Elliptio complanata*) with total shell lengths ranging from 90 to 111 mm were selected for the study during sampling at the reference site. A list of whole animal fresh weights (in g), and total shell lengths, widths and heights (in mm) are provided for each animal in Table 4 by cage number and compartment for tracking purposes.

3.3 Mussel Transplantation

3.3.1 Reference Site

Mussels were collected in the Ottawa River from an area with background tritium concentrations at the mouth of the Schyan River (Quebec), upstream of AECL's Chalk River Laboratories site (Figure 1). Mussels were collected and placed into lidded, plastic buckets containing water from the reference site to prevent uptake of tritium by mussels prior to initiation of the study. Mussels were then transported to the laboratory on the CRL site. Individuals were quickly measured, weighed and alpha-numerically numbered (as shown in Table 4), and were separated by placing them into labeled nylon bags. Animals were then replaced into the lidded buckets of water from the reference site until initiation of the transplantation, which was carried out on the same day as mussel collection. Concentrations of HTO and OBT measured in surface waters and mussels collected from this background location are provided in Table 5.

3.3.2 Deployment of Mussel Cages 1 and 2 (Water Exposure Pathway)

Mussel Cages 1 and 2 were deployed on 5 July 2005 at 14:00 hours. Cages 1 and 2 were positioned in Perch Lake at a water depth of approximately 0.75 m. These cages were placed on cinder blocks, such that the mussels received tritium exposure only through interaction with the water column. Upon initiation of the transplantation study (at time 0), mussels were transferred from the lidded buckets containing water from the reference site to buckets containing water from Perch Lake. In this way, all mussels received initial tritium exposure at approximately the same time, despite the 10 to 15 minute time period required for transfer from buckets to the numbered cage compartments. Mussels were placed into the cage compartments and began filtering within less than five minutes. No mussel mortality occurred in Cages 1 or 2 over the course of the 86-day study. Algal growth, which accumulated on the cages over the course of the study was not removed, as it did not appear to alter water flow within the cages.

3.3.3 Deployment of Mussel Cages 3 and 4 (Water and Sediment Exposure Pathways)

Mussel Cages 3 and 4 were deployed on 7 July 2004 at 14:00 hours. Cages 3 and 4 were positioned in Perch Lake at the sediment-to-water interface at a water depth of approximately 0.5 m, just inshore of Cages 1 and 2 (Figure 2), such that the mussels received tritium exposure through the sediment and water pathways. Each cage compartment was filled with sandy surface sediments originating from the area surrounding the cages to a depth of approximately 5 to 10 cm, a depth that enabled mussels to position themselves in an upright position with their siphons pointed upwards, as they do in natural systems. The sediments were collected to a depth of approximately 5 to 10 cm and were added to the cages several hours prior to transplantation of the mussels to allow settling of any suspended particulates.

Again, as for Cages 1 and 2, upon initiation of mussel transplantation into Cages 3 and 4 (at time 0), the mussels were transferred from the lidded buckets containing water from the reference site to buckets containing water from Perch Lake. Mussels were then placed into the cage compartments and were visually monitored. In general, mussels began positioning themselves in an upright position within five minutes of transplantation. Again, no mussel mortality occurred in Cages 3 or 4 over the course of the 88-day transplantation study.

4. STUDY MEASUREMENTS

4.1 Tritium Monitoring

4.1.1 Collection of Mussel Samples

The individual animals that made up the composite sample at each time point are specified in Table 6. Mussel samples were collected on an expanding time-step over the course of an 88-day period. Upon collection, mussels were immediately placed into air-tight Mason jars to avoid tritium exchange with the atmosphere, and the jars containing the mussels were frozen until processing for tritium analysis could be carried out. In general, it was necessary to composite soft tissues from 3 to 4 individuals to gain the biomass required for HTO and OBT analysis. The average water content of mussel tissue was 89.0% (by weight), with little variability among individual animals.

4.1.2 Collection of Surface Water Samples

Water samples were collected in triplicate at each sampling time point (Table 7) in the vicinity of each of the mussel cages (Figure 2). In doing so, sampling bottles were opened at the depth where the mussels were filtering. The samples were then left standing to allow suspended sediments to settle out and 10 mLs of water were subsequently transferred to scintillation vials. HTO concentrations in all water samples were determined by liquid scintillation counting (LSC).

4.1.3 Collection of Surface Sediment Samples

Sediment samples were collected by hand at a depth of 5 to 10 cm in the vicinity of the mussel cages at each mussel sampling time point and were placed in Ziplock bags that were sealed at depth. Water was extracted from a subset of sediment samples (Table 7) by freeze-drying and these sediments were analyzed for HTO concentration by LSC. The pressure during freeze-drying fell between 10^{-4} and 10^{-5} Torr and the temperature ranged from 0 to -4^{o} C. The remaining solid material was washed with tritium-free water to remove the exchangeable OBT. Sediments were oven-dried until no change in mass occurred and dried sediments were combusted in a combustion tube. The combustion water was analyzed by LSC to quantify OBT concentrations.

4.1.4 Collection of Plankton

Plankton samples were collected in the Perch Lake water column on 20 September 2004 just offshore of the cages to quantify tritium levels in mussel dietary items (as an input parameter for modeling purposes). HTO levels of 4153, 4101 and 4068 Bq/L were found in the plankton samples. Corresponding FWT concentrations in Perch Lake surface waters at the time of plankton sampling were 4091, 4066 and 4038 Bq/L. By comparison, an OBT concentration of 2914 ± 42 Bq/L was measured in the composite plankton sample. Note that it was not possible to measure OBT in individual samples due to the relatively large biomass required for OBT analysis.

4.2 Water Temperature

Perch Lake surface water temperatures were taken continuously using a temperature probe set to integrate values over 5-minute time intervals. The probe was positioned a few centimetres above the sediment-water interface.

5. INPUT DATA

Measured tritium concentrations in water (HTO) and mussel soft tissues (HTO and OBT) collected at the background location are provided in Table 5. In addition, water and sediment tritium levels measured at each time point are summarized in Table 7. Plankton HTO and OBT data are listed in Section 4.1.4 above.

In cases where more than one value is listed for a given parameter, separate composite samples were taken close to the same location to facilitate measurement of variability.

5.1 Uncertainties

Counting errors in the HTO concentrations in Perch Lake surface water and sediments were generally less than 2%. Counting errors for OBT concentrations are typically less than 5%, although additional uncertainty can arise due to difficulties in removing exchangeable OBT from the samples and during the combustion process. The total uncertainty in the OBT measurements is estimated to be approximately 20%. Differences among replicate samples from the same location may be larger because of natural variability.

6. SCENARIO CALCULATIONS

Using the information provided in the Sections above, calculate:

(i.) HTO and non-exchangeable OBT concentrations (Bq/L) in mussels exposed only via water (i.e. in Cages 1 and 2) for each measurement time-point, as specified in Table 8;

(ii.) HTO and non-exchangeable OBT concentrations (Bq/L) in mussels exposed via both water and sediments (i.e. in Cages 3 and 4) for each measurement time-point, as specified in Table 9; and

(iii.) 95% confidence intervals on all predictions in (i) - (ii).

Results should be submitted using Tables 8 and 9.

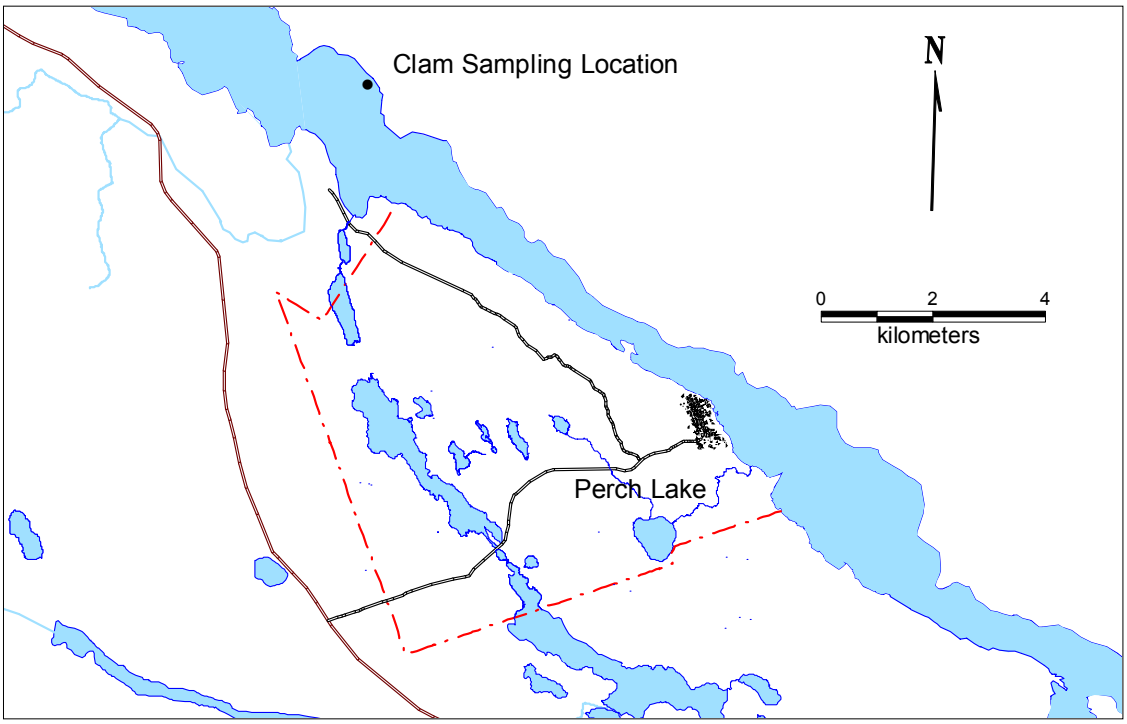

Figure 1: Map depicting the location of the reference site in the Ottawa River where freshwater mussels (*Elliptio complanata*) were collected, relative to the site of mussel transplantation in Perch Lake on AECL's Chalk River Laboratories site.

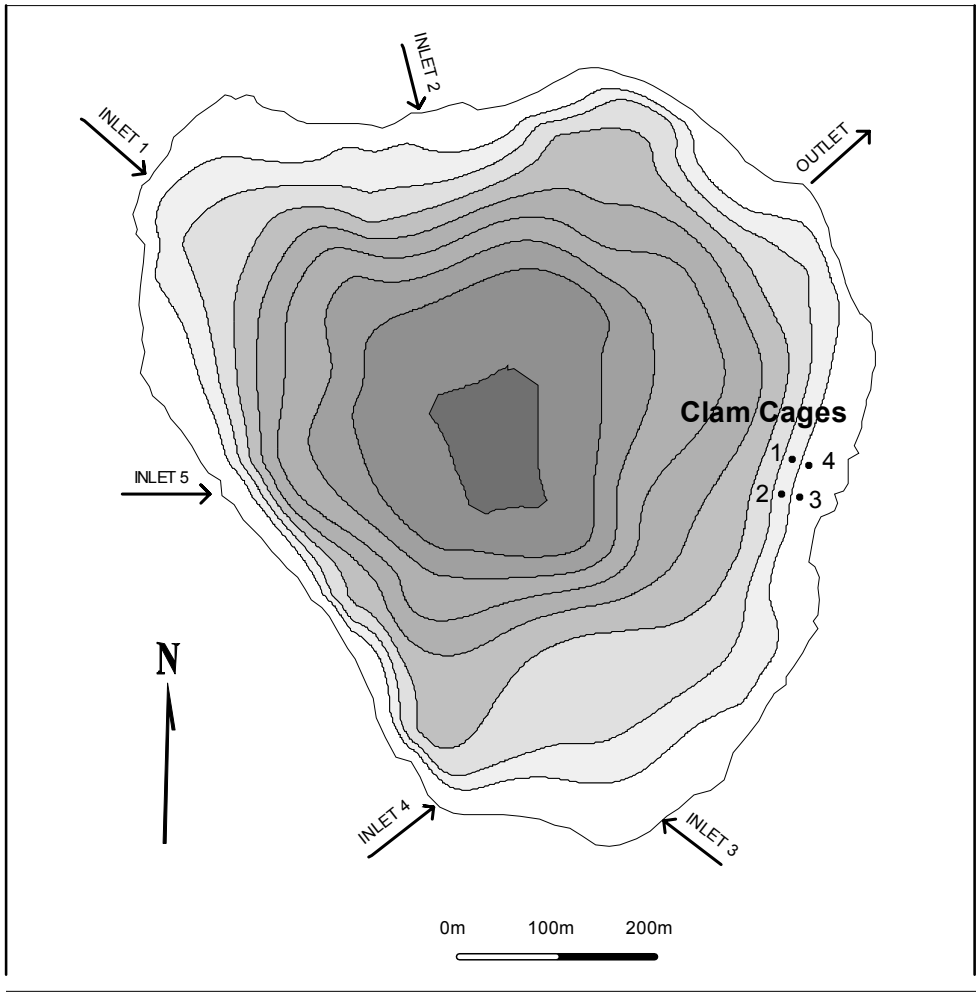

Figure 2: Map of Perch Lake depicting the location of inflowing and outflowing streams, depth contours (in metres) and locations of mussel transplantation cages.

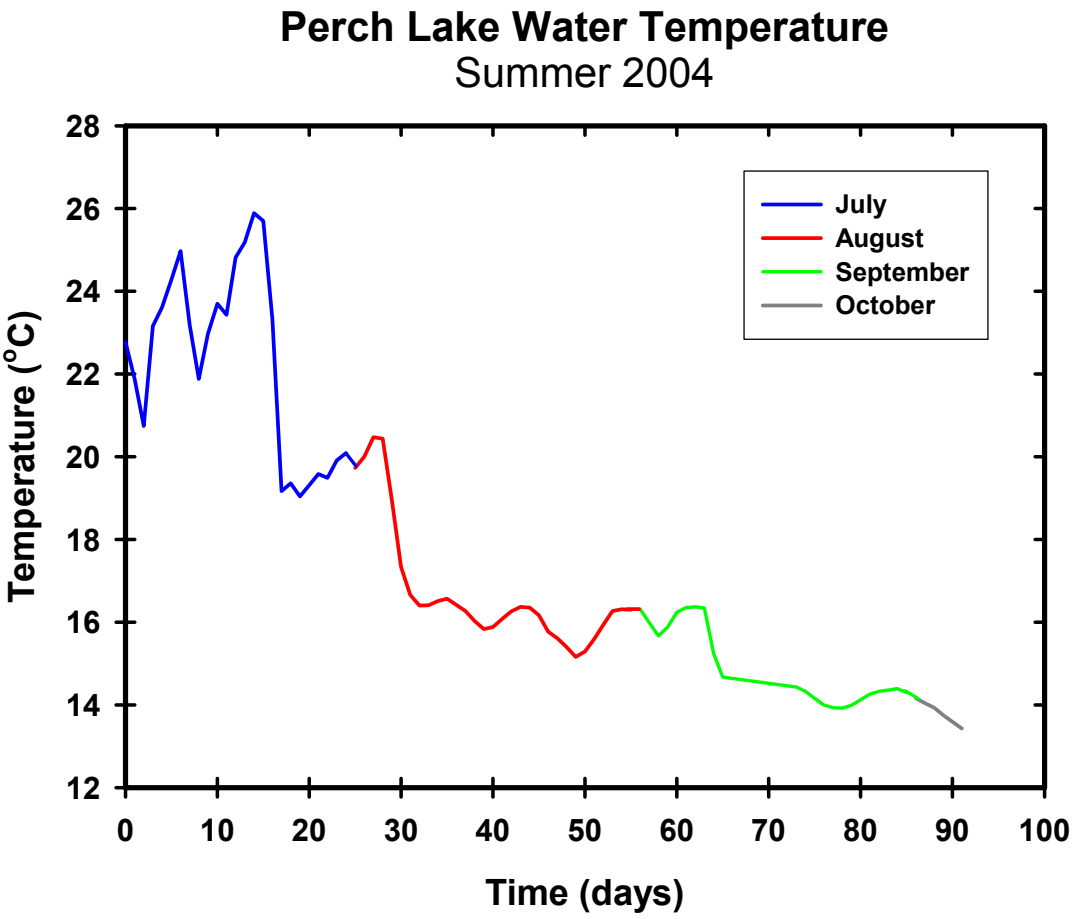

Figure 3: Perch Lake water temperatures over the course of the mussel transplantation study. Temperature measurements were integrated over 5-minute time intervals between 5 July 2004 and 6 October 2004. The experiment starting time (t0) for Cages 1 and 2 was 5 July 2004 at 14:00, whereas the starting time for Cages 3 and 4 was 7 July 2004 at 14:00. Comparable temperature trends were observed for air temperatures.

Table 1: Daily average Perch Lake water temperature (T) data, based on integrated measurements taken over 5-minute intervals. Temperature data were not available for the period between September 11 and 17 due to a problem wih the temperature probe. Raw temperature data are available upon request.

Date	Mean Temperature T (^{o}C)	n	Standard Error of 5-Minute Values (^{o}C)
07-Jul-04	22.77	150	0.127
08-Jul-04	21.88	288	0.0950
09-Jul-04	20.74	288	0.0658
10-Jul-04	23.16	288	0.192
11-Jul-04	23.61	288	0.0900
12-Jul-04	24.28	288	0.102
13-Jul-04	24.97	288	0.0903
14-Jul-04	23.19	288	0.0549
15-Jul-04	21.88	288	0.0523
16-Jul-04	22.97	288	0.110
17-Jul-04	23.70	288	0.108
18-Jul-04	23.43	288	0.120
19-Jul-04	24.82	288	0.100
20-Jul-04	25.18	288	0.160
21-Jul-04	25.89	288	0.0916
22-Jul-04	25.70	288	0.0802
23-Jul-04	23.31	288	0.127
24-Jul-04	19.17	288	0.0574
25-Jul-04	19.36	288	0.0088
26-Jul-04	19.04	288	0.0206
27-Jul-04	19.31	288	0.0064
28-Jul-04	19.58	288	0.0058
29-Jul-04	19.49	288	0.0088
30-Jul-04	19.91	288	0.0041
31-Jul-04	20.09	288	0.0029
01-Aug-04	19.73	288	0.0122
02-Aug-04	20.00	288	0.0056
03-Aug-04	20.47	288	0.0065
04-Aug-04	20.44	288	0.0197
05-Aug-04	18.93	288	0.0635
06-Aug-04	17.33	288	0.0172
07-Aug-04	16.66	288	0.0124
08-Aug-04	16.40	288	0.0013
09-Aug-04	16.41	288	0.0010
10-Aug-04	16.51	288	0.0028
11-Aug-04	16.57	288	0.0015
12-Aug-04	16.42	288	0.0032
13-Aug-04	16.27	288	0.0025
14-Aug-04	16.03	288	0.0072
15-Aug-04	15.83	288	0.0005

Date	Mean Temperature T (°C)	n	Standard Error of 5-Minute Values (°C)
16-Aug-04	15.88	288	0.0022
17-Aug-04	16.08	288	0.0041
18-Aug-04	16.26	288	0.0029
19-Aug-04	16.37	288	0.0012
20-Aug-04	16.35	288	0.0061
21-Aug-04	16.17	288	0.0045
22-Aug-04	15.77	288	0.0129
23-Aug-04	15.61	288	0.0040
24-Aug-04	15.40	288	0.0167
25-Aug-04	15.16	288	0.0014
26-Aug-04	15.29	288	0.0047
27-Aug-04	15.59	288	0.0051
28-Aug-04	15.93	288	0.0063
29-Aug-04	16.27	288	0.0040
30-Aug-04	16.31	288	0.0003
31-Aug-04	16.30	288	0.0004
01-Sep-04	16.32	288	0.0011
02-Sep-04	15.99	288	0.0172
03-Sep-04	15.67	288	0.0010
04-Sep-04	15.88	288	0.0072
05-Sep-04	16.24	288	0.0037
06-Sep-04	16.35	288	0.0014
07-Sep-04	16.37	288	0.0017
08-Sep-04	16.34	288	0.0016
09-Sep-04	15.24	288	0.0390
10-Sep-04	14.67	177	0.0022
18-Sep-04	14.43	156	0.0007
19-Sep-04	14.33	288	0.0029
20-Sep-04	14.16	288	0.0033
21-Sep-04	14.00	288	0.0023
22-Sep-04	13.93	288	0.0010
23-Sep-04	13.92	288	0.0006
24-Sep-04	13.99	288	0.0017
25-Sep-04	14.12	288	0.0023
26-Sep-04	14.26	288	0.0021
27-Sep-04	14.33	288	0.0005
28-Sep-04	14.36	288	0.0006
29-Sep-04	14.39	288	0.0004
30-Sep-04	14.30	288	0.0026
01-Oct-04	14.16	288	0.0024
02-Oct-04	14.04	288	0.0021
03-Oct-04	13.93	288	0.0023
04-Oct-04	13.75	288	0.0032
05-Oct-04	13.59	288	0.0028
06-Oct-04	13.43	171	0.0034

Table 2: Summary of transplanted freshwater mussel exposure pathways under the various test conditions.

Cage No.	Exposure Medium	
	Water	***Sediments***
1	X	-
2	X	-
3	X	X
4	X	X

Table 3: Summary of layout of mussel transplantation cages and mussel numbering scheme. Cages were set up as a matrix and individual mussels were numbered as alphanumerical coordinates of alphabetical 'columns' and numerical 'rows' to facilitate tracking of each mussel in terms of tritium uptake rates relative to mussel body size.

Column / Row	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1	A1	B1	C1	D1	E1	F1	G1	H1
2	A2	B2	C2	D2	E2	F2	G2	H2
3	A3	B3	C3	D3	E3	F3	G3	H3
4	A4	B4	C4	D4	E4	F4	G4	H4
5	A5	B5	C5	D5	E5	F5	G5	H5
6	A6	B6	C6	D6	E6	F6	G6	H6
7	A7	B7	C7	D7	E7	F7	G7	H7
8	A8	B8	C8	D8	E8	F8	G8	H8

Table 4: Summary of weight and length measurements of freshwater mussel specimens

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
A1	Cage No. 1	64.40	96	46	24
	Cage No. 2	60.03	92	49	23
	Cage No. 3	100.77	111	58	28
	Cage No. 4	78.33	98	49	24
A2	Cage No. 1	95.19	98	54	28
	Cage No. 2	57.35	92	45	21
	Cage No. 3	74.09	96	51	27
	Cage No. 4	64.90	95	49	25
A3	Cage No. 1	62.94	90	48	25
	Cage No. 2	68.62	93	46	26
	Cage No. 3	122.57	109	57	33
	Cage No. 4	97.13	103	53	27
A4	Cage No. 1	83.50	103	49	27
	Cage No. 2	61.38	90	45	24
	Cage No. 3	62.44	94	46	26
	Cage No. 4	60.93	94	45	24
A5	Cage No. 1	79.23	99	50	26
	Cage No. 2	91.42	105	51	30
	Cage No. 3	85.65	103	50	28
	Cage No. 4	90.77	105	53	28
A6	Cage No. 1	102.05	102	56	27
	Cage No. 2	58.94	93	47	23
	Cage No. 3	87.57	104	56	28
	Cage No. 4	77.47	103	51	25
A7	Cage No. 1	69.89	95	49	24

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	74.51	96	52	26
	Cage No. 3	56.50	92	52	20
	Cage No. 4	100.44	109	57	29
A8	Cage No. 1	83.58	96	51	27
	Cage No. 2	72.89	94	50	26
	Cage No. 3	61.72	92	46	25
	Cage No. 4	70.48	90	51	25
B1	Cage No. 1	73.07	96	46	27
	Cage No. 2	90.96	100	54	30
	Cage No. 3	82.79	101	53	26
	Cage No. 4	69.16	90	49	25
B2	Cage No. 1	75.31	95	48	26
	Cage No. 2	98.10	105	54	32
	Cage No. 3	86.19	107	55	25
	Cage No. 4	117.87	109	59	31
B3	Cage No. 1	77.75	95	51	27
	Cage No. 2	79.26	95	52	29
	Cage No. 3	75.66	99	53	27
	Cage No. 4	73.90	100	51	26
B4	Cage No. 1	94.55	104	54	28
	Cage No. 2	73.14	94	51	27
	Cage No. 3	72.95	98	51	26
	Cage No. 4	85.76	102	52	26
B5	Cage No. 1	66.31	94	49	26
	Cage No. 2	70.63	94	53	27
	Cage No. 3	74.28	103	51	27
	Cage No. 4	73.64	100	49	24
B6	Cage No. 1	98.34	106	56	27

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	62.84	90	51	35
	Cage No. 3	101.33	110	54	30
	Cage No. 4	83.43	104	52	25
B7	Cage No. 1	70.41	95	49	26
	Cage No. 2	65.22	96	47	27
	Cage No. 3	91.92	100	54	28
	Cage No. 4	77.91	93	50	26
B8	Cage No. 1	70.29	103	47	22
	Cage No. 2	70.75	90	51	29
	Cage No. 3	74.20	99	50	28
	Cage No. 4	78.51	98	49	26
C1	Cage No. 1	67.95	97	47	25
	Cage No. 2	73.15	100	46	26
	Cage No. 3	102.75	108	53	31
	Cage No. 4	69.39	95	47	27
C2	Cage No. 1	80.67	104	54	25
	Cage No. 2	62.98	94	58	26
	Cage No. 3	68.65	97	47	24
	Cage No. 4	84.76	100	50	27
C3	Cage No. 1	57.44	93	45	23
	Cage No. 2	77.36	100	55	26
	Cage No. 3	71.25	99	48	27
	Cage No. 4	57.55	95	47	21
C4	Cage No. 1	79.36	104	52	25
	Cage No. 2	79.90	98	48	28
	Cage No. 3	83.91	105	53	29
	Cage No. 4	94.57	105	55	26
C5	Cage No. 1	73.39	96	50	25

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	63.48	95	52	23
	Cage No. 3	84.51	103	51	29
	Cage No. 4	67.19	102	50	22
C6	Cage No. 1	86.02	99	49	30
	Cage No. 2	81.52	100	52	26
	Cage No. 3	78.38	104	51	26
	Cage No. 4	94.18	105	50	29
C7	Cage No. 1	83.06	101	52	26
	Cage No. 2	82.38	102	59	30
	Cage No. 3	70.38	98	47	27
	Cage No. 4	78.38	100	51	27
C8	Cage No. 1	74.35	101	46	26
	Cage No. 2	119.84	109	57	33
	Cage No. 3	81.21	104	54	27
	Cage No. 4	80.26	98	50	27
D1	Cage No. 1	101.37	103	58	27
	Cage No. 2	113.44	110	56	30
	Cage No. 3	117.32	106	60	30
	Cage No. 4	70.64	95	50	24
D2	Cage No. 1	101.61	101	55	29
	Cage No. 2	96.75	104	56	30
	Cage No. 3	78.61	102	55	28
	Cage No. 4	80.66	99	52	26
D3	Cage No. 1	83.65	102	50	25
	Cage No. 2	97.71	101	59	30
	Cage No. 3	77.04	100	50	26
	Cage No. 4	81.01	101	51	25
D4	Cage No. 1	68.54	96	49	29

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	116.83	110	51	33
	Cage No. 3	71.61	94	50	26
	Cage No. 4	82.94	104	51	26
D5	Cage No. 1	69.29	95	49	26
	Cage No. 2	68.78	93	53	25
	Cage No. 3	103.58	109	55	30
	Cage No. 4	78.11	99	51	25
D6	Cage No. 1	78.06	99	49	27
	Cage No. 2	98.91	104	50	30
	Cage No. 3	74.73	93	53	24
	Cage No. 4	86.86	105	51	26
D7	Cage No. 1	74.73	99	50	25
	Cage No. 2	56.23	94	50	24
	Cage No. 3	91.28	99	54	29
	Cage No. 4	74.43	100	51	26
D8	Cage No. 1	68.01	95	45	25
	Cage No. 2	78.77	94	52	28
	Cage No. 3	76.94	96	51	24
	Cage No. 4	67.74	91	45	26
E1	Cage No. 1	70.48	101	50	23
	Cage No. 2	94.40	100	58	30
	Cage No. 3	75.84	100	51	27
	Cage No. 4	56.26	93	46	24
E2	Cage No. 1	83.36	104	53	26
	Cage No. 2	93.48	100	52	30
	Cage No. 3	85.21	96	51	29
	Cage No. 4	74.88	94	52	25
E3	Cage No. 1	75.97	96	50	27

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	87.74	104	53	29
	Cage No. 3	108.61	101	54	34
	Cage No. 4	67.46	100	50	21
E4	Cage No. 1	94.02	106	55	32
	Cage No. 2	84.80	101	54	29
	Cage No. 3	121.49	106	58	32
	Cage No. 4	82.10	91	50	28
E5	Cage No. 1	68.08	97	48	25
	Cage No. 2	78.27	98	50	29
	Cage No. 3	71.57	98	50	25
	Cage No. 4	93.52	106	54	26
E6	Cage No. 1	94.80	99	50	29
	Cage No. 2	59.17	90	48	24
	Cage No. 3	67.72	94	49	26
	Cage No. 4	79.62	100	54	24
E7	Cage No. 1	76.23	96	54	25
	Cage No. 2	90.52	102	57	29
	Cage No. 3	67.71	98	46	25
	Cage No. 4	68.97	94	47	26
E8	Cage No. 1	72.53	96	48	26
	Cage No. 2	84.61	102	53	28
	Cage No. 3	91.71	100	54	28
	Cage No. 4	64.47	94	48	25
F1	Cage No. 1	82.47	100	56	25
	Cage No. 2	106.65	108	55	31
	Cage No. 3	118.56	106	56	35
	Cage No. 4	72.55	102	50	23
F2	Cage No. 1	71.93	92	45	26

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	83.38	100	53	30
	Cage No. 3	93.37	108	55	27
	Cage No. 4	75.37	97	51	24
F3	Cage No. 1	64.14	95	46	25
	Cage No. 2	70.93	99	49	26
	Cage No. 3	84.16	98	54	28
	Cage No. 4	77.31	100	50	27
F4	Cage No. 1	64.66	90	43	27
	Cage No. 2	62.23	94	52	25
	Cage No. 3	52.74	95	44	22
	Cage No. 4	56.74	92	46	24
F5	Cage No. 1	57.42	96	46	20
	Cage No. 2	66.86	94	52	27
	Cage No. 3	86.67	96	56	27
	Cage No. 4	61.29	93	48	23
F6	Cage No. 1	62.56	91	45	24
	Cage No. 2	81.23	96	55	28
	Cage No. 3	87.95	99	51	27
	Cage No. 4	55.34	101	50	26
F7	Cage No. 1	77.95	96	50	25
	Cage No. 2	86.17	100	50	30
	Cage No. 3	78.95	101	50	25
	Cage No. 4	88.66	105	51	25
F8	Cage No. 1	103.22	102	52	32
	Cage No. 2	80.08	98	50	27
	Cage No. 3	78.25	96	56	27
	Cage No. 4	79.17	96	50	26
G1	Cage No. 1	93.02	100	50	29

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	84.70	102	56	28
	Cage No. 3	75.21	92	49	29
	Cage No. 4	97.28	101	53	28
G2	Cage No. 1	87.85	100	51	27
	Cage No. 2	81.72	96	52	29
	Cage No. 3	88.85	100	50	29
	Cage No. 4	68.91	100	49	24
G3	Cage No. 1	81.58	98	52	27
	Cage No. 2	92.11	101	59	28
	Cage No. 3	73.52	95	48	27
	Cage No. 4	57.64	95	43	25
G4	Cage No. 1	78.90	103	49	25
	Cage No. 2	76.98	101	49	28
	Cage No. 3	96.64	104	51	30
	Cage No. 4	65.54	95	49	25
G5	Cage No. 1	81.23	98	50	26
	Cage No. 2	85.68	103	54	27
	Cage No. 3	87.76	99	52	26
	Cage No. 4	59.86	93	46	24
G6	Cage No. 1	75.92	104	50	26
	Cage No. 2	69.04	93	49	24
	Cage No. 3	87.04	94	51	26
	Cage No. 4	78.69	101	48	26
G7	Cage No. 1	82.61	99	51	26
	Cage No. 2	102.42	109	58	28
	Cage No. 3	90.70	105	52	29
	Cage No. 4	77.30	95	50	28
G8	Cage No. 1	101.38	101	55	30

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	111.92	105	54	32
	Cage No. 3	77.33	93	51	27
	Cage No. 4	71.08	95	49	26
H1	Cage No. 1	99.11	99	51	29
	Cage No. 2	58.79	95	49	23
	Cage No. 3	78.30	96	50	27
	Cage No. 4	88.84	99	52	28
H2	Cage No. 1	102.84	106	58	29
	Cage No. 2	76.84	100	52	27
	Cage No. 3	73.16	101	51	22
	Cage No. 4	70.65	97	48	25
H3	Cage No. 1	89.06	105	54	27
	Cage No. 2	91.36	105	57	27
	Cage No. 3	76.54	97	50	27
	Cage No. 4	62.94	91	48	25
H4	Cage No. 1	71.87	92	48	24
	Cage No. 2	97.37	104	60	30
	Cage No. 3	78.72	94	49	27
	Cage No. 4	78.80	100	50	26
H5	Cage No. 1	99.63	107	59	29
	Cage No. 2	82.38	102	54	29
	Cage No. 3	93.95	105	54	28
	Cage No. 4	59.08	91	46	23
H6	Cage No. 1	86.78	101	50	27
	Cage No. 2	79.57	96	51	30
	Cage No. 3	79.56	101	51	25
	Cage No. 4	75.75	98	51	25
H7	Cage No. 1	87.75	100	51	28

Cell No.	Cage No.	*Mussel Measurements*			
		Fresh Weight (g)	**Shell Length (mm)**	**Shell Width (mm)**	**Shell Height (mm)**
	Cage No. 2	92.28	99	55	30
	Cage No. 3	87.52	102	51	26
	Cage No. 4	76.51	94	50	25
H8	Cage No. 1	99.67	107	56	27
	Cage No. 2	67.62	96	49	26
	Cage No. 3	73.50	101	48	25
	Cage No. 4	65.86	93	49	25

Table 5: Summary of free-water tritium (HTO) and organically-bound tritium (OBT) concentrations in various sample types collected at the background locations in the Ottawa River, upstream of CRL. Values measured for freshwater mussels represent the initial tritium levels at Time 0 of the study.

Sample Type	HTO (Bq/L)	OBT (Bq/L)
Surface Water	< 10	Not applicable
Freshwater Mussels	< 10	< 15

Table 6: Summary of individual mussels collected from Cages 1 to 4 in Perch Lake at each sampling time point. The mussels taken from a given cage at a given time were composited to produce a single sample for tritium analysis.

Time After Mussel Transplantation	Water Only Exposure		Sediment and Water Exposure		Comments
	Cage 1	*Cage 2*	*Cage 3*	*Cage 4*	
1 hour (all cages)	A6	G5	C6	B3	
	G2	H3	E5	D8	
	H5	H7	H8	F5	
2 hours (all cages)	C4	B4	G2	A6	
	A8	E7	B5	E1	
	F3	H2	E8	E4	
4 hours (all cages)	A7	A3	A5	C3	
	B3	C6	E3	E2	
	D7	E3	G7	E6	
7 hours (all cages)	B5	B6	C5	D2	
	E6	D5	A8	E7	
	G3	E4	H3	G4	
19 hours (all cages)	B4	B3	A1	B5	Duplicate samples (2 sets of 3) taken for QA purposes.
	D2	B8	C3	B6	
	H4	F1	D4	D1	
	C7	A8	E7	E5	
	E5	D1	G4	F2	
	H7	F7	G6	F8	
24 hours (all cages)	D6	F2	A3	A8	
	E3	F5	B8	C1	
	G5	D6	G5	F4	
48 hours (all cages)	C2	C4	B2	A1	
	D8	E6	E6	D5	
	F5	G3	D5	F6	

Time After Mussel Transplantation	Water Only Exposure		Sediment and Water Exposure		Comments
	Cage 1	*Cage 2*	*Cage 3*	*Cage 4*	
96 hours (all cages)	B2	A4	B1	A3	Duplicate samples taken for QA purposes.
	B8	A6	C4	B7	
	D5	C5	D6	D3	
	E1	E2	E2	G5	
	F4	F8	H4	C6	
	H8	G4	H7	H2	
8 days (all cages)	C8	A7	A2	A4	
	F6	C1	D7	D7	
	G4	H5	F7	F3	
14 days (all cages)	B6	B1	A4	C4	Duplicate samples taken for QA purposes.
	B7	B7	B6	B1	
	C1	D4	E1	C7	
	E7	D8	F6	F7	
	G6	G1	F8	G1	
	H6	G7	G1	H7	
18 days (Cages 1 & 2)	D3	D3	B7	B2	
19 days (Cages 3 & 4)	F2	C7	F4	D6	
	G7	E8	H6	H8	
25 days (Cages 1 & 2)	C6	C8	A7	C5	Duplicate samples taken for QA purposes.
27 days (Cages 3 & 4)	D4	D2	C1	C8	
	E4	D7	C2	F1	
	F7	E5	D8	G6	
	G1	H4	F3	H1	
	G8	F6	H5	H6	
36 days (Cages 1 & 2)	A5	A2	C8	B8	
35 days (Cages 3 & 4)	D1	C3	E4	G7	
	H1	H8	H2	E3	
42 days (Cages 1 & 2)	C3	B2	A6	A2	Duplicate samples taken for QA purposes.
41 days (Cages 3 & 4)	C5	B5	B4	C2	
	E2	E1	D1	G2	
	F1	F3	D2	G3	
	H3	G8	G3	H4	
	E8	H6	G8	H5	

Time After Mussel Transplantation	Water Only Exposure		Sediment and Water Exposure		Comments
	Cage 1	*Cage 2*	*Cage 3*	*Cage 4*	
86 days (Cages 1 & 2) 84 days (Cages 3 & 4)	A1	A1	B3	A7	Duplicate samples taken for QA purposes.
	A2	A5	C7	B4	
	A3	C2	D3	D4	
	A4	F4	F1	E8	
	F8	G2	F2	G8	
	B1	G6	H1	H3	
	H2				

Table 7: Summary of tritium input data for use in the Perch Lake dynamic mussel transplantation scenario.

Time After Mussel Transplantation	*Water HTO (Bq/L)*		*Surface Sediments* (Between Cages 1 and 2)		*Water HTO (Bq/L)*		*Surface Sediments* Between Cages 3 and 4	
	Cage 1	Cage 2	HTO (Bq/L)	OBT (Bq/L)	Cage 3	Cage 4	HTO (Bq/L)	OBT (Bq/L)
0 hour (all cages)	4,800	4,787	-	-	4,645	4,799	-	-
	4,847	4,880	-	-	4,688	4,763	-	-
	4,689	4,775	-	-	4,656	4,636	-	-
1 hour (all cages)	4,735	4,829	-	-	4,646	4,729	4,310	1,020 ± 26
	4,785	4,685	-	-	4,689	4,792	4,296	
	4,830	4,734	-	-	4,844	4,795	-	-
2 hours (all cages)	4,637	4,711	3,926	994 ± 23	4,762	4,715	-	-
	4,641	4,625	3,961		4,685	4,638	-	-
	4,575	4,795	-	-	4,766	4,709	-	-
4 hours (all cages)	4,718	4,636	-	-	4,661	4,718	-	-
	4,705	4,747	-	-	4,711	4,835	-	-
	4,598	4,683	-	-	4,758	4,660	-	-
7 hours (all cages)	4,804	4,611	-	-	4,753	4,688	-	-
	4,638	4,745	-	-	4,653	4,769	-	-
	4,752	4,719	-	-	4,566	4,685	-	-
19 hours (all cages)	4,821	4,796	-	-	4,456	4,378	-	-
	4,784	4,840	-	-	4,350	4,356	-	-
	4,743	4,716	-	-	4,329	4,339	-	-

Time After Mussel Transplantation	*Water HTO (Bq/L)*		*Surface Sediments* (Between Cages 1 and 2)		*Water HTO (Bq/L)*		*Surface Sediments* Between Cages 3 and 4	
	Cage 1	**Cage 2**	**HTO (Bq/L)**	**OBT (Bq/L)**	**Cage 3**	**Cage 4**	**HTO (Bq/L)**	**OBT (Bq/L)**
24 hours (all cages)	4,683	4,734	4,015	700 ± 7	4,464	4,522	3,802	1,248 ± 50
	4,832	4,677	4,025	-	4,371	4,478	3,854	-
	4,683	4,774	-	-	4,386	4,427	-	-
48 hours (all cages)	4,645	4,799	-	-	4,429	4,503	-	-
	4,688	4,763	-	-	4,371	4,329	-	-
	4,656	4,636	-	-	4,574	4,648	-	-
96 hours (all cages)	4,597	4,615	-	-	4,526	4,549	-	-
	4,650	4,609	-	-	4,547	4,722	-	-
	4,699	4,605	-	-	4,617	4,534	-	-
8 days (all cages)	4,678	4,634	-	-	4,431	4,270	-	-
	4,749	4,697	-	-	4,312	4,348	-	-
	4,696	4,683	-	-	4,200	4,376	-	-
14 days (all cages)	4,410	4,472	3,993	571 ± 9	4,150	4,212	3,845	1,403 ± 66
	4,417	4,533	3,919	-	4,128	4,182	3,795	-
	4,298	4,365	-	-	4,171	4,137	-	-
18 days (Cages 1 & 2) 19 days (Cages 3 & 4)	4,438	4,347	-	-	4,470	4,415	-	-
	4,367	4,337	-	-	4,385	4,417	-	-
	4,276	4,347	-	-	4,374	4,443	-	-
25 days (Cages 1 & 2) 27 days (Cages 3 & 4)	4,383	4,329	-	-	4,136	4,073	-	-
	4,412	4,420	-	-	3,985	4,088	-	-
	4,299	4,359	-	-	4,132	4,143	-	-

Time After Mussel Transplantation	*Water HTO (Bq/L)*		*Surface Sediments* (Between Cages 1 and 2)		*Water HTO (Bq/L)*		*Surface Sediments* Between Cages 3 and 4	
	Cage 1	**Cage 2**	**HTO (Bq/L)**	**OBT (Bq/L)**	**Cage 3**	**Cage 4**	**HTO (Bq/L)**	**OBT (Bq/L)**
36 days (Cages 1 & 2)	4,238	4,393	-	-	4,150	4,328	3,894	1,159 ± 33
35 days (Cages 3 & 4)	4,268	4,313	-	-	4,176	4,272	3,876	-
	4,387	4,191	-	-	4,180	4,281	-	-
42 days (Cages 1 & 2)	4,102	4,173	3,802	704 ± 17	4,069	4,088	-	-
41 days (Cages 3 & 4)	4,182	4,137	3,857	-	4,094	4,066	-	-
	4,109	4,079	-	-	3,977	3,991	-	-
[a] 77 days	4,091	-	-	-	-	-	-	-
	4,066	-	-	-	-	-	-	-
	4,038	-	-	-	-	-	-	-
86 days (Cages 1 & 2)	3,930	4,088	-	-	4,046	3,955	3,274	1,829 ± 28 (Cage 3)
84 days (Cages 3 & 4)	3,973	3,949	-	-	4,038	4,062	3,840	1,981 ± 57 (Cage 4)

[a] Triplicate water samples were collected in area where plankton samples were taken. Water data are likely representative of a well-mixed condition in the lake.

Table 8: Summary of calculational endpoints for the dynamic Perch Lake mussel transplantation scenario for Cages 1 and 2.

Time After Transplantation	*Surface Water Only Tritium Exposure* (Cages 1 and 2)			
	Mussel HTO Concentration (Bq/L)	**95% Confidence Interval**	**Mussel OBT Concentration (Bq/L)**	**95% Confidence Interval**
1 hour				
2 hours				
4 hours				
7 hours				
19 hours				
24 hours				
48 hours				
96 hours				
8 days				
14 days				
18 days				
25 days				
36 days				
42 days				
86 days				

Table 9: Summary of calculational endpoints for the dynamic Perch Lake mussel transplantation scenario for Cages 3 and 4.

Time After Transplantation	*Surface Water and Sediment Tritium Exposure* (Cages 3 and 4)			
	Mussel HTO Concentration (Bq/L)	**95% Confidence Interval**	**Mussel OBT Concentration (Bq/L)**	**95% Confidence Interval**
1 hour				
2 hours				
4 hours				
7 hours				
19 hours				
24 hours				
48 hours				
96 hours				
8 days				
14 days				
19 days				
27 days				
35 days				
41 days				
84 days				