Results of the Kloiya River Resistivity Counter 2010

Skeena Fisheries Report SK 157

Dean Peard[1]

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[1] Ministry of Environment – Skeena Region – Fish & Wildlife Branch

Executive Summary

A Logie 2100C resistivity counter was installed at the Kloiya River on March 10, 2010. The counter electrodes are located within a plastic tube 150 cm in length with a inside diameter of 37.5 cm. The tube was placed near the top of a vertical slot fishway located approximately 2 kilometres upstream of the Kloiya River estuary. Steelhead migrating through the fishway passed through the culvert resulting in a change in conductivity that was analysed by an algorithm and recorded by the counter. A row of data for each event was comprised of the date, time, direction of travel and peak signal strength. Electrical power was provided by a stream engine that utilizes the head of water at the site to generate hydro electric power. Power levels were constant through the project, and the resistivity counter remained operational through the survey. Hourly water temperatures were collected on Hobo Pro v2 temperature data loggers during the project. The lowest mean daily water temperature recorded was 3.60°C on March 13. The highest mean daily water temperature was 13.02°C on May 18.

The first steelhead was recorded on March 14, 2010. There was very limited upstream steelhead migration through the fishway until early April. March represented 18% (n=18) of the total uncorrected up counts, April 58% (n=80) and May 28% (n=41). The highest daily uncorrected upstream count was ten on April 18. Between March 10 and May 20, 2010 the counter recorded a total of 139 up counts, 83 down counts and 94 changes in conductivity that did not meet criteria to be classified as a migrating fish. Counter efficiency was calculated on trace data collected in 2007. In 2007, trace data was recorded for 74% of the data recorded by counter. Trace data indicates that the counter efficiency for upstream migrants is 94% and 76% for downstream migrants. After corrections for counter efficiency, the 2010 steelhead escapement, upstream of the Kloiya River dam is estimated to be 52.

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1.0 Introduction

The Kloiya River watershed is located approximately 15 km southeast of Prince Rupert, B.C. (Fig 1). This coastal watershed provides spawning and rearing habitat for populations of chinoook salmon (*Oncorhynchus tshawytscha)*, chum salmon (*Oncorhynchus keta)*, coho salmon (*Oncorhynchus kisutch)*, sockeye salmon (*Oncorhynchus nerka)*, steelhead (*Oncorhynchus mykiss)*, coastal cutthroat trout (*Oncorhynchus clarkii)*, Dolly Varden (*Salvelinus malma*), pink salmon (*Oncorhynchus gorbuscha)*, general sculpins (*Cottidae*) and threespine stickleback (*Gasterosteus aculeatus*) (*Habitat Wizard. Aug 2007*). The Kloiya River is a fourth order stream with an approximate length of two km. A dam with a vertical height of approximately seven meters was constructed in 1949 two km upstream of the Kloiya River estuary. This structure was built to provide a source of water for the Skeena Cellulose pulp mill. A vertical slot fishway approximately 50 meters in length was incorporated into the dam's construction to facilitate fish passage upstream of the structure.

Kloiya River winter-run steelhead are known to spawn and rear in the mainstem Kloiya River as well as tributaries to Taylor Lake (Diana Creek) and Prudhomme Lake (Prudhomme Creek) (*Tredger, 1981*). The river provides the closest winter-run steelhead angling opportunity for anglers from Prince Rupert and Port Edward. The recreational steelhead fishery typically begins in late November and continues into April *(Beere pers. comm)*. The short fishable section of the river below the dam is subject to significant and rapid fluctuations in flow and stage, and has a limited number of angling locations that are accessible by trail.

Information about the Kloiya Watershed steelhead population is limited to a study undertaken in 1981 by Ministry of Environment commissioned by the Salmonid Enhancement Program and the resistivity counter projects in 2006, 2007, 2009 and 2010. The 1981 study was limited to quantifying juvenile steelhead abundance, smolt production and estimating values for habitat capacity thresholds. In 2005, the Ministry of Environment (*MoE*) began investigating the potential of using the Kloiya as an index stream for monitoring the abundance trends of north coast winter run steelhead using resistivity technology. This report compiles information from project years 2006, 2007, 2009 and 2010.

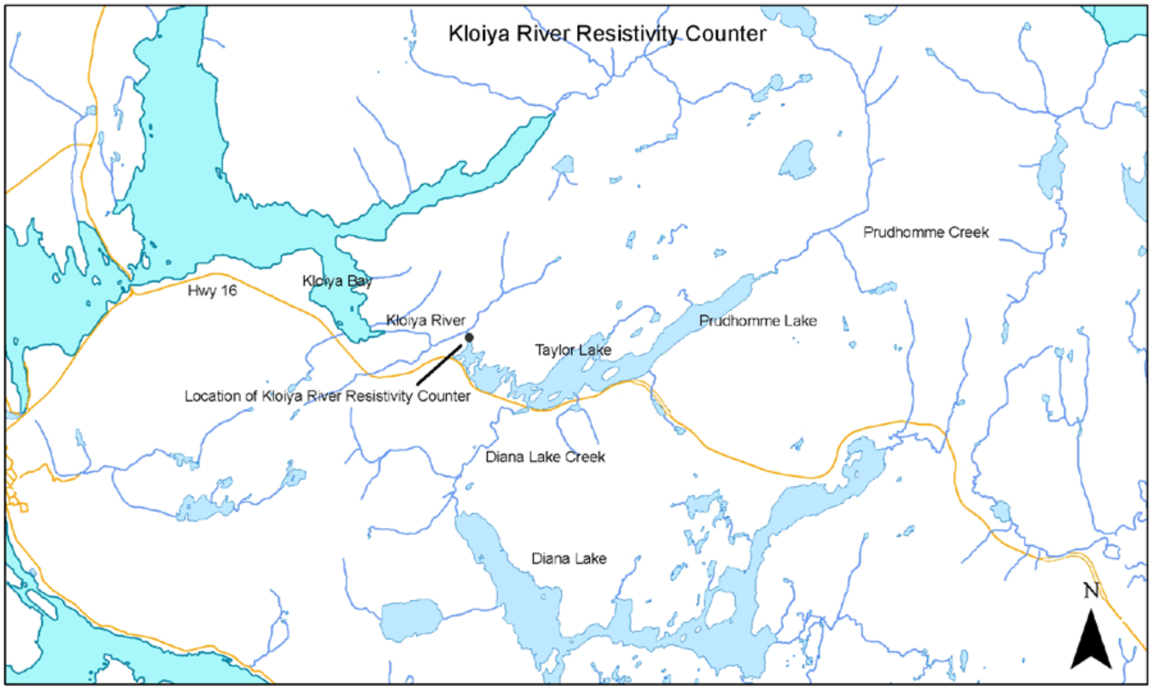

Figure 1. Location of Kloiya River resistivity counter.

2.0 Project Design/Methods

The Kloiya River was surveyed in November 2005 to determine a suitable location to install and operate a Logie 2100C resistivity counter (*Aquantic Ltd, Scotland*). All resistivity counters operate in conjunction with three electrodes placed on top of a fixed weir, transportable flat pad, or inside of a tube. The three electrodes create a field that monitors the conductivity of the water within the field. The counter recalibrates the measured conductivity every 30 minutes. When a fish passes through the field the change in conductivity is recorded by the counter. The signal is analyzed by an algorithm and a row of data is produced indicating the date, time, direction of travel and peak signal size. Changes in conductivity not determined to be caused by a fish are classified as events. The fishway was selected as the location for the counter based on several advantageous attributes. The location was adjacent to a secure storage shed to store the electronic equipment, the site was accessible by vehicle, the head of water at the dam could be used to generate power for the equipment and fish migrating through the fishway would be forced to swim through the resistivity counter tube. The tube type counter was developed and tested on the Bonaparte

River near Cache Creek, B.C. (*McCubbing 2003*). The counter tube on the Kloiya River has a inside diameter of 37.5 cm and an overall length of 150 cm. The tube is attached to aluminum grate and lowered into existing concrete slots in the fishway (Pic 1).

Picture 1. Kloiya River resistivity counter tube

The location of the counter was selected due to the high probability of successfully enumerating adult steelhead at that location. Although steelhead are known to spawn below the dam, the decision was made to locate the counter at the fishway and enumerate a proportional representation of the annual Kloiya River steelhead escapement. Tredger 1981, estimated that at capacity, spawning tributaries upstream of the fishway represented 53% of annual watershed steelhead smolt production. A subsequent qualitative habitat survey of the mainstem Kloiya River, in April 2006, indicated that there is a limited amount of spawning and fry habitat available below the dam inferring that a majority of the steelhead recruitment occurs in tributaries above the fishway (*Beere pers. comm).*

In 2010, data produced by the Logie 21000 C was downloaded on to a Lenovo T500 Thinkpad lap top computer (*IBM, Armonk, New York, USA*) using version 1.0.1 of the fish counter control program (*Aquantic Ltd, Scotland*). This software was used to change counter parameters and download data. Count data was downloaded weekly. Three Hobo Pro v2 temperature data loggers (*Onset*

Computer Corporation, Pocasset, MA) recorded hourly water temperatures (°C) One data logger recorded temperature in the fishway, and the other two were located in the mainstem Kloiya River below the dam.

Electrical power for the counter system was generated by a Stream Engine (*Energy Systems and Design Ltd, Sussex NB*) which utilized the head of water at the site to keep the batteries charged and the equipment functioning.

3.0 Equipment Settings

3.1 Logie Counter Settings

Logie 2100C counter settings are dependent upon several parameters. Water conductivity is the primary metric for determining counter settings. Specific conductance and Total Dissolved Solids (TDS) values for the Kloiya River are very low, 15 μmhos/cm and 10 mg/l respectively. As a result, the counter gain was set at a value of 400 to compensate for the low conductivity. In comparison, counter gain was set at 250 in 2006 which was determined to be to low. Threshold values required for fish identification was set at 20. Counter software used during the 2010 project was version 9.10.

4.0 Results

4.1 Counter Efficiency

The Kloiya River resistivity counter was installed and operational on March 10, 2010. The first steelhead was recorded on March 14, 2010 and the last steelhead was recorded on May 20, 2010. During this time period, the counter recorded 139 up counts, 83 down counts and 94 events. Events indicate a change in conductivity that was not recognized by the counter algorithm as a fish. A total of 316 rows of data were recorded as upstream counts, downstream counts and events (Table1).

Date	Time	Description	P.S.S
14-Mar	18:14:06	U	45
14-Mar	19:49:23	D	127
16-Mar	14:44:42	U	40
16-Mar	22:45:55	D	27
17-Mar	7:03:59	E	27
19-Mar	14:24:03	U	46
20-Mar	1:00:36	U	61
20-Mar	1:24:45	D	111
20-Mar	13:02:17	U	46
22-Mar	0:58:55	U	126
22-Mar	1:12:58	E	127
22-Mar	1:53:55	D	103
22-Mar	4:57:11	U	52
22-Mar	5:41:19	D	126
23-Mar	3:59:20	D	27
23-Mar	12:14:52	U	38
24-Mar	15:31:11	U	59
24-Mar	15:46:31	D	127
26-Mar	13:13:01	U	71
29-Mar	16:21:50	U	49
29-Mar	16:48:09	U	91

Table 1**.** Example of text data collected from counter in 2010**.**

To estimate counter efficiency, counter data is calibrated with trace data. The trace data provides a visual record of the counter data that can be compared to the counter algorithm’s classification. Trace data can only be collected on a dedicated lap top computer that must be left on site to record the trace data. It is expected that trace data collected in 2007 is a reasonable estimate of counter efficiencies on a annual basis. In 2007, 115 or (74%) of the counter records had corresponding trace data that can be used for analysis. These data were collected between March 8 and May 13, 2007. Two letter codes were used to compare text and trace data and determine event classification (Table 2).

UU	Upstream fish classified as a upstream fish
UE	Upstream fish classified as a event
DD	Downstream fish classified as a downstream fish
DE	Downstream fish classified as a event
EE	Non fish event correctly classified as a event

Table 2. Codes used to compare trace and text data.

Counter efficiency for upstream counts was determined by dividing the number correctly classified up counts UU (83) by the total number of up counts UU+UE (88). This results in a upstream efficiency estimate of 94%. This is a significant improvement compared to the 81% upstream efficiency calculated in 2006 (*Peard 2007*). Counter efficiency for downstream migrants was calculated by dividing the correctly classified number of down counts DD (19) by the total number of down counts DD+ DE (25). Therefore, the counter efficiency for downstream migrants was calculated to be 76%. Downstream efficiency also benefitted from a higher gain setting. The 2006 downstream counter efficiency was estimated to be 58% (*Peard 2007*). The remaining eleven events were changes in conductivity that were not related to fish passage. Classification errors, upstream or downstream, primarily involved fish traces not breaking the threshold required to be identified as fish. This may be due to very low conductivity in combination with changes in swim height as the fish migrates through the field. Figures 2 and 3 shows examples of downstream and upstream migrants, recorded in 2006, incorrectly classified as an event.

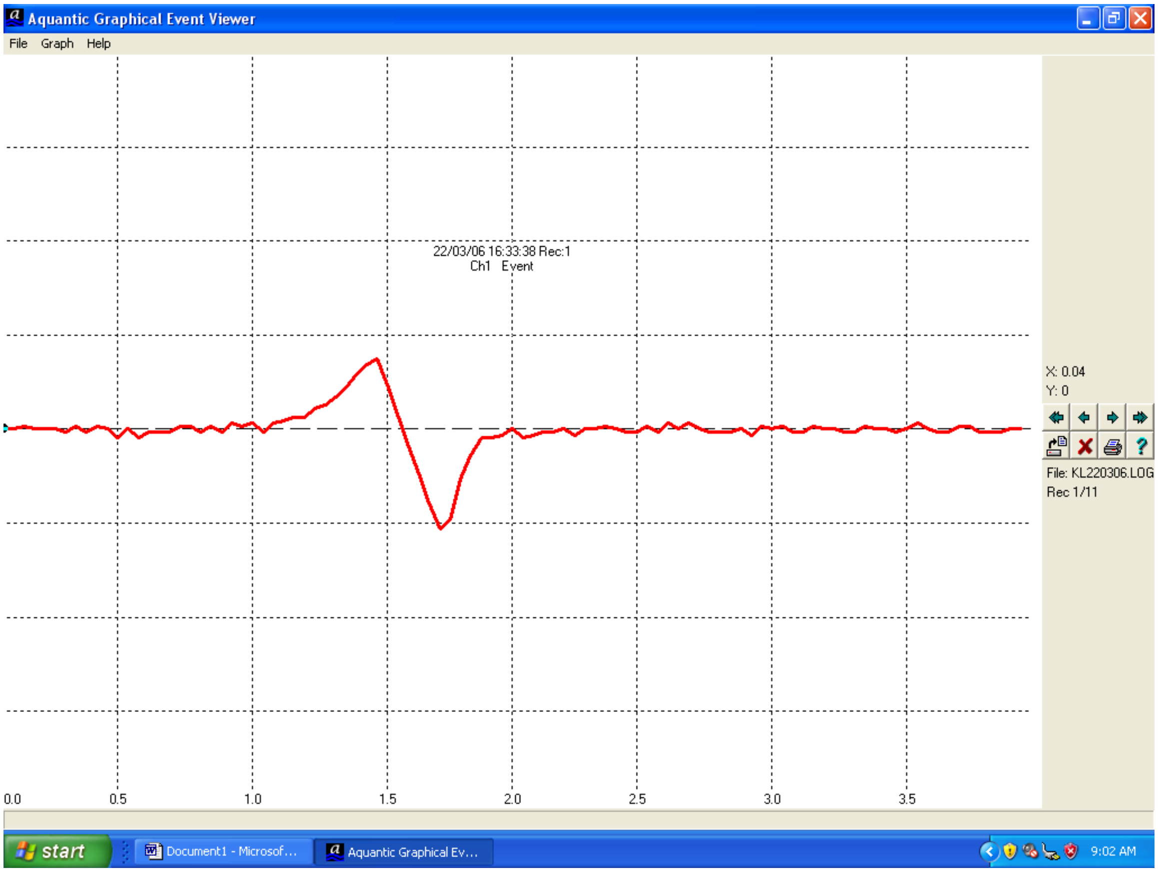

Figure 2. Downstream migrant incorrectly classified as a non fish event.

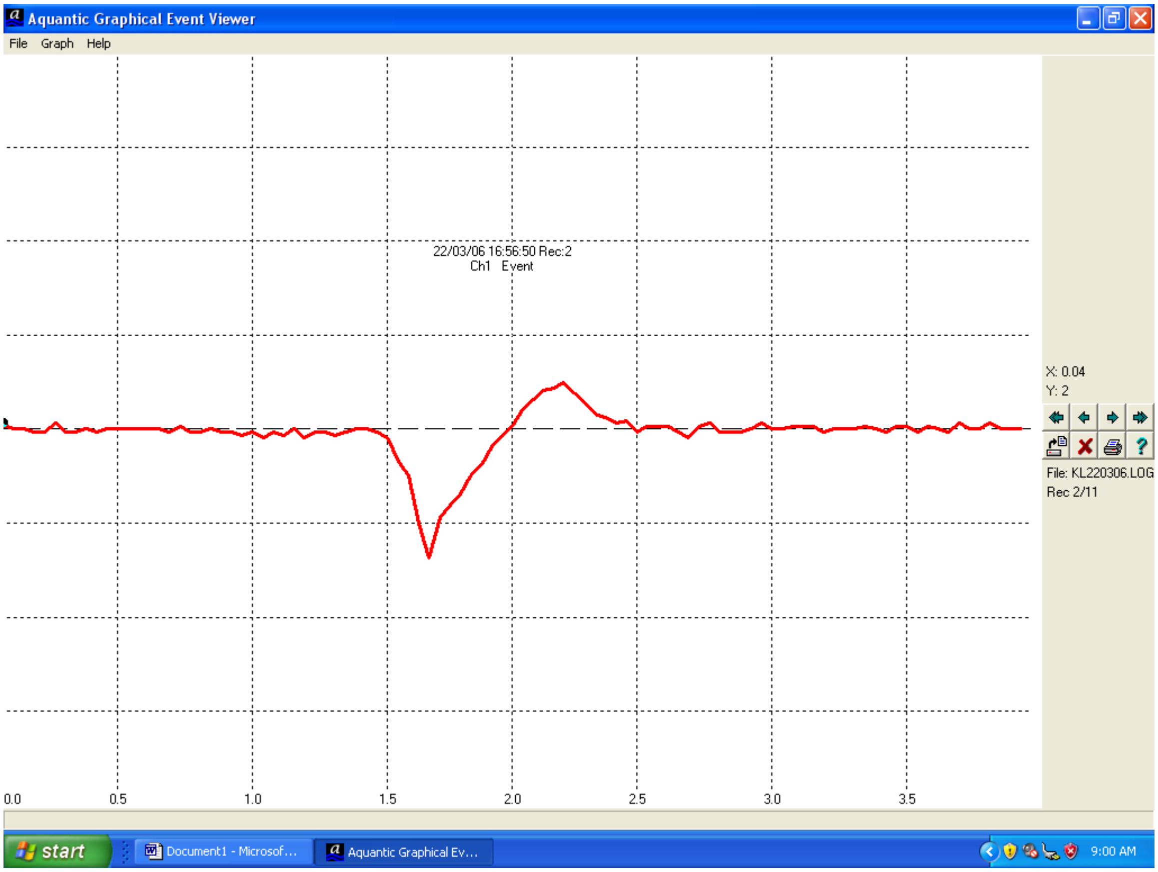

Figure 3. Upstream migrant incorrectly classified as a non fish event.

Sudden changes in water conductivity not related to fish migration are also recorded by the counter. Some examples of non fish events recorded by the counter include river otters, beavers, air entrainment and sudden changes in water flow (*MCcubbing pers. comm*). These trace patterns are significantly different from fish traces and visual analysis can distinguish between changes in conductivity related to fish and non fish events. Figure 4 is an example of a change in conductivity not related to fish migration.

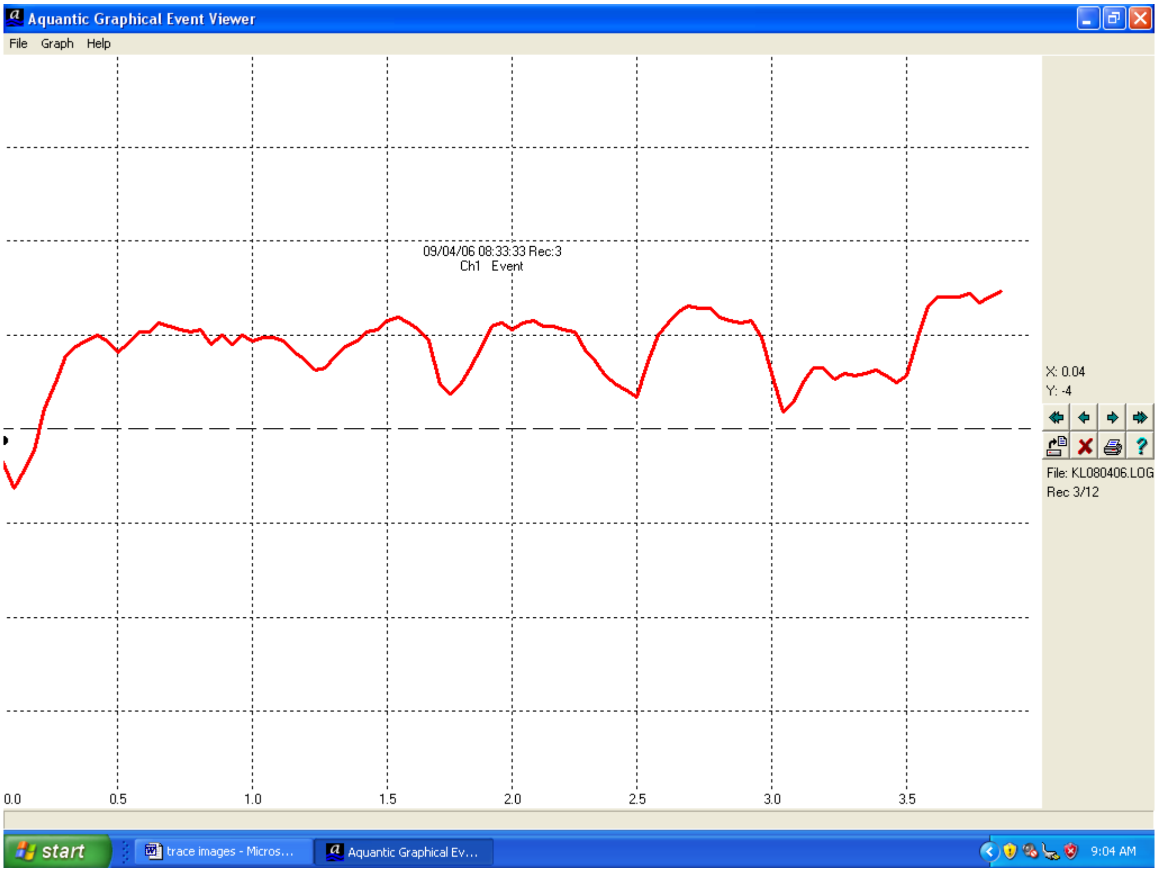

Figure 4. Change in conductivity correctly classified as a non fish event.

4.3 Escapement Estimate

Since daily down counts did not exceed daily up counts, near the end of the project, it is assumed that kelt emigration did not bias the results. A correction factor is applied to the rows of data logged as events (not indicated as up or down migrants) where trace data is unavailable. Trace data, collected in 2007, indicated that 22% of the events logged by the counter were upstream migrants. In comparison, 30% of the events were downstream migrants. These values are applied to the 2010 events where trace data does not exist. In 2010 this value is equal to 94. To estimate up counts, 94 is multiplied by 0.22. Therefore, it is estimated that 21upstream migrants were not correctly classified. The estimate for downstream migrants is 94 multiplied by 0.30. It is estimated that 25 downstream migrants were not correctly classified. The escapement estimate for Kloiya River winter run steelhead is estimated by subtracting down counts from the up counts recorded during the project which is equal to 52. Figure 5 shows the escapement estimates for 2006, 2007,2009 and 2010.

U+UE-D+DE=escapement (139+21)- (108+25) = 52

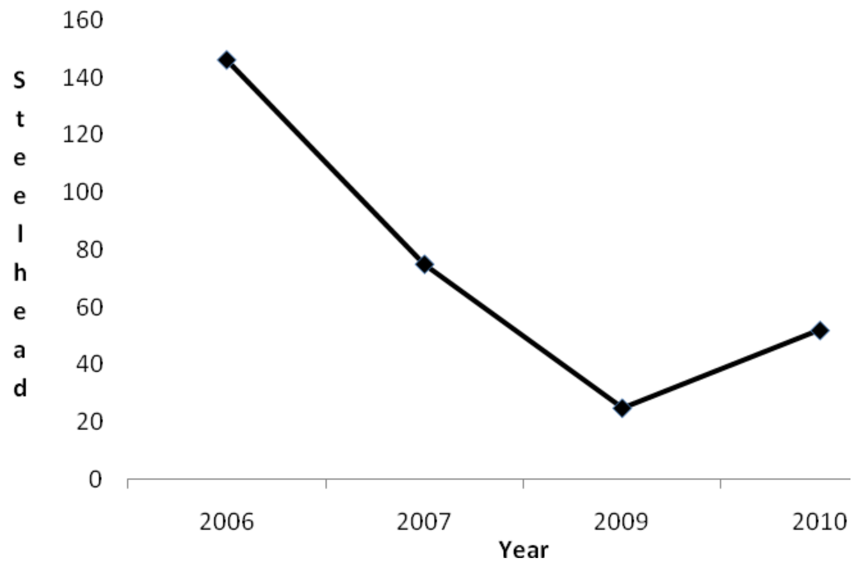

Figure 5. Kloiya River steelhead escapement estimates 2006, 2007, 2009 and 2010

4.4 Run Timing

Anglers begin to capture Kloiya River steelhead in the month of November with peak catch reportedly occurring in March and April *(Beere pers. comm).* Data collected in 2006 and 2007 indicated that steelhead are not typically migrating through the fishway until March and as a result the counter was not installed and operational until March 10, 2010. Information from anglers suggested that there are typically steelhead present below the Kloiya Dam in December, January and February. However, the first steelhead recorded by the counter typically occurs in March. This indicates that Kloiya River steelhead run timing into the lower river is significantly different from the migration through the fishway. For the purposes of this report run timing refers to the migration through the fishway and into Taylor Lake.

To gain a better understanding in run timing trends, uncorrected daily net up counts are used to demonstrate run timing. In 2010, the peak daily upstream count occurred on April 18 (Fig 6). In comparison, the peak daily count in previous years occurred on April 24 in 2006, April 24 in 2007 and May 13 in 2009 (Fig 7).

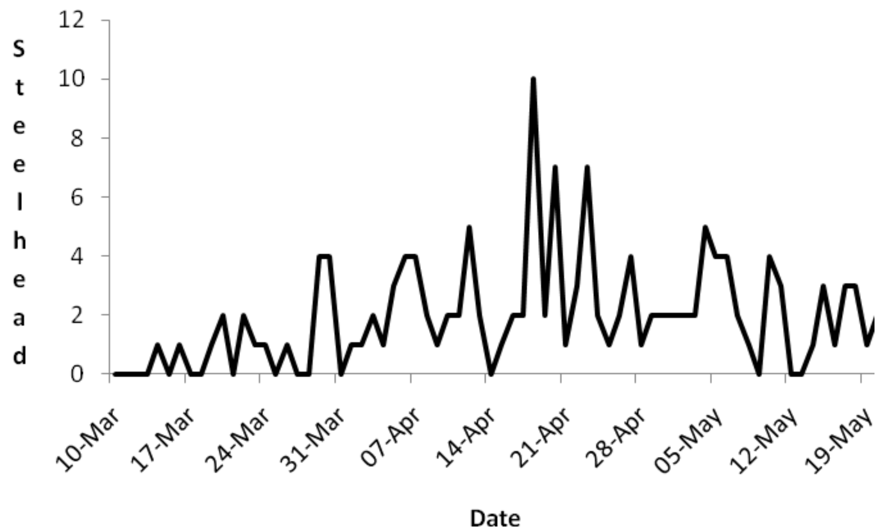

Figure 6 Uncorrected daily up counts March 10 to May 20, 2010.

Run timing in 2010 was comparable to run timing in 2006 and 2007. Limited upstream migration was observed in both years until early April when upstream counts increased. In both years, peak daily upstream counts occurred in late April (Fig 7). In 2009, there were no steelhead recorded migrating through the counter until May 1 and the peak count was recorded on May 13 (Fig 7).

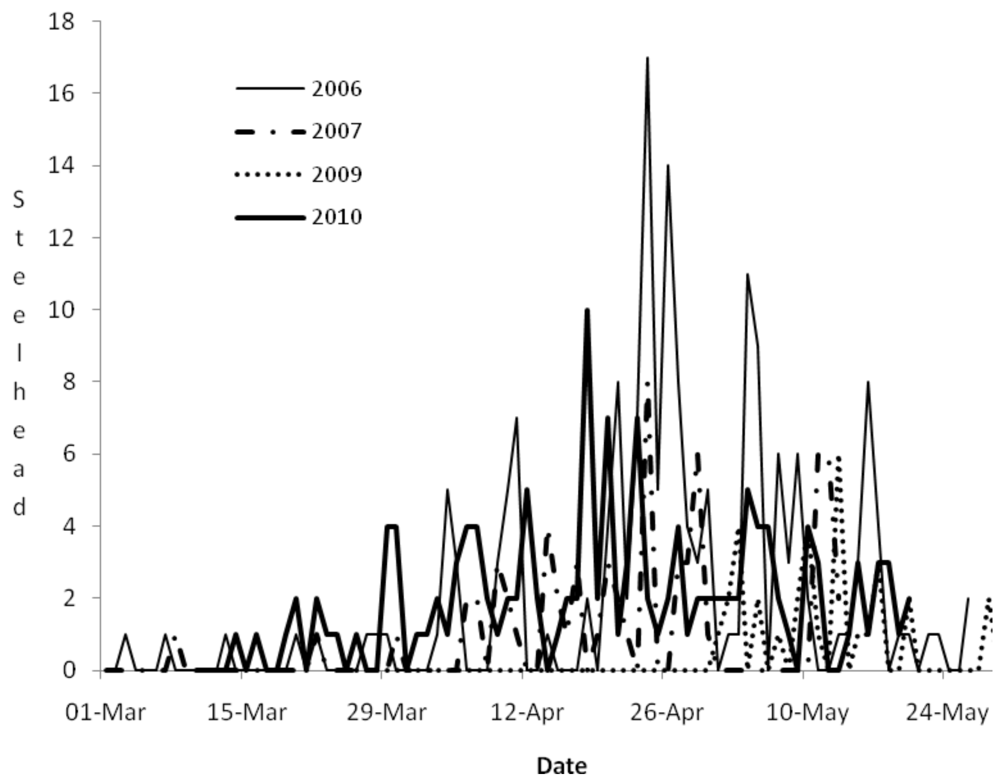

Figure 7. Kloiya River steelhead run timing 2006, 2007, 2009 and 2010.

4.5 Environmental Parameters

Hourly water temperatures were recorded by three Hobo Pro v2 temperature data loggers. Water temperatures were recorded between March 10, 2010 and May 20, 2010. Water temperature ranged between 3.46˚C (March 12 at 0800) and 14.1˚C (May 18 at 1700). Mean water temperature for the duration of the 2010 project is 7.24˚ C (SD=2.76) (Fig 8). Water temperature in 2010 were warmer relative to the same dates in 2006 and 2007. The mean temperature, during the same time period in 2006, was 5.73˚C. And in 2007 the mean temperature to May 13 was 4.73˚C. The three water temperature profiles, during this time period, show that water temperatures were warmer in 2010 than other project years (Fig 9).

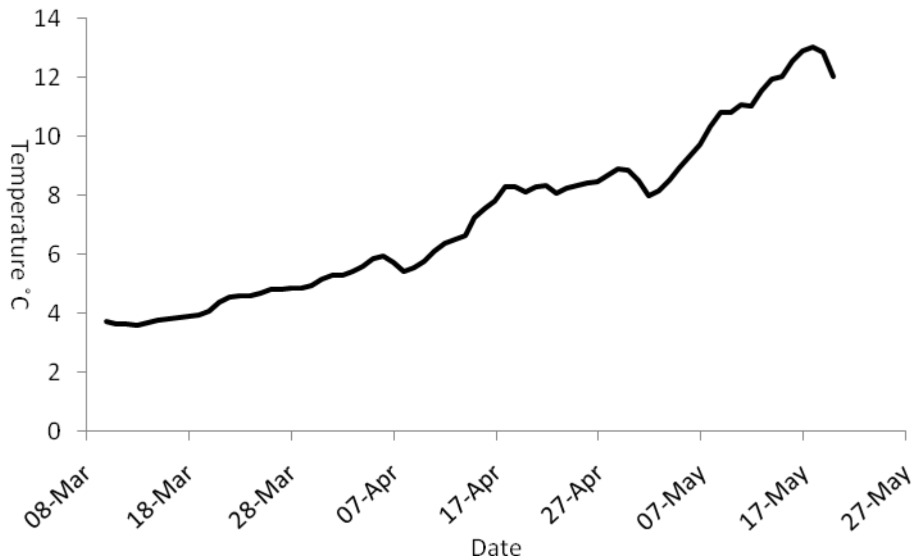

Figure 8 Mean daily water temperatures Kloiya River 2010.

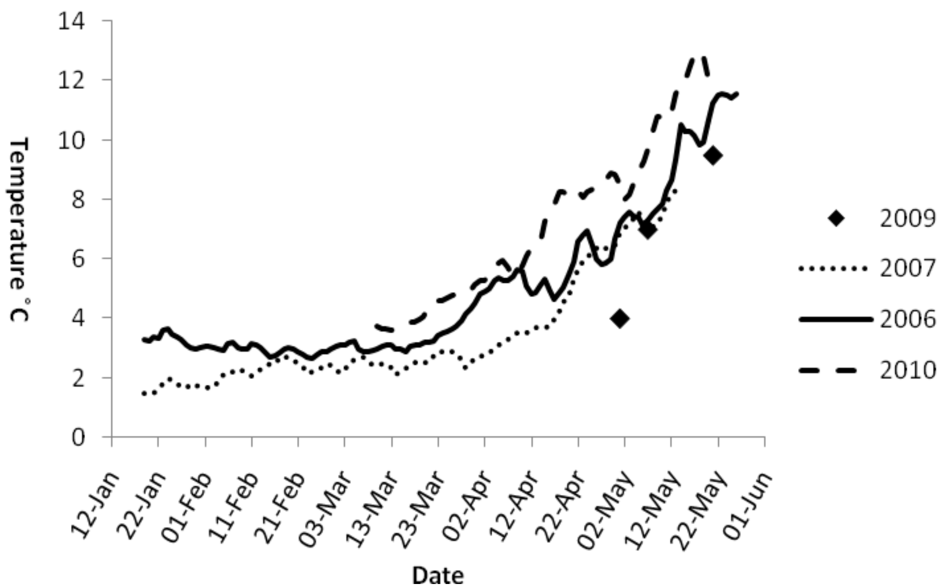

Figure 9. Daily water temperatures 2006, 2007, 2009 and 2010.

Kloiya River level and flow is controlled by the Kloiya River Dam. A water survey station maintained by Environment Canada is located approximately 300 meters downstream of the structure. The station collects and records data that is accessible from the Environment Canada website. The hydrograph in Figure 10 is produced using data from that website. Water flow down the fishway can be manipulated independently of the dam's gate, however, visual observation during site visits indicated that flow in the fishway was directly related to flow in the main channel. Gaps in the time series are where data was unavailable from the Environment Canada website.

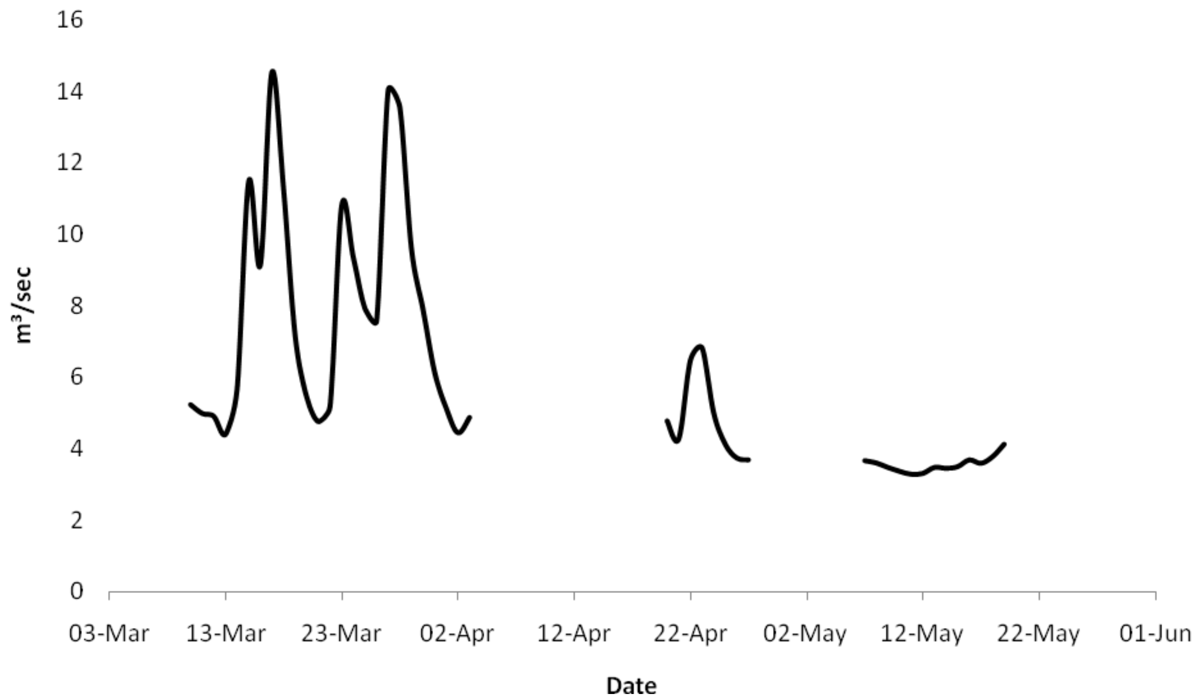

Figure 10 Mean daily flow (m^3/sec) in the Kloiya River March 10 to May 19 2010 (Env Canada survey station Kloiya River).

Figure 11 shows steelhead migration through the fish way at various flows. Missing flow data from the 14 days leading up to the peak steelhead migration make it difficult to analyze how flow may affect migration during the project.

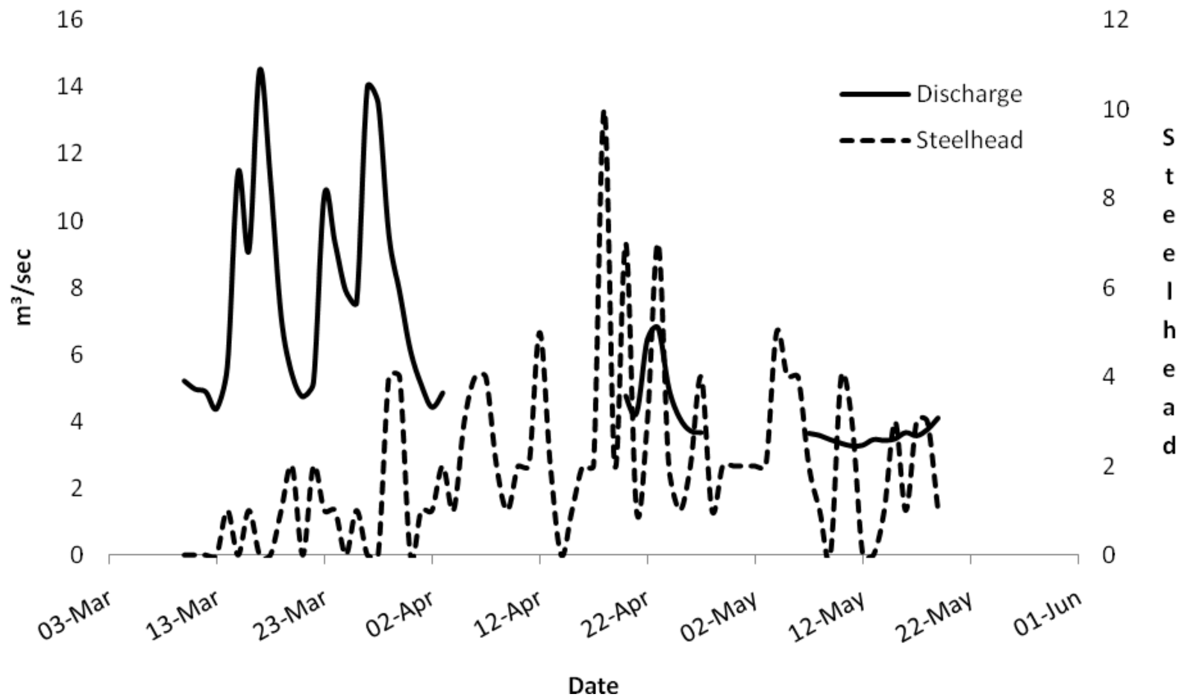

Figure 11 Mean daily flow (m³/sec) and daily steelhead migration in the Kloiya River March 10 May 19 2010 (Env Canada survey station Kloiya River).

4.6 Migration Behaviour through the Fishway

When the Kloiya River dam was built in 1949, a vertical slot fishway was incorporated into the construction to facilitate fish migration above the structure. The fishway is approximately 50 meters long with a small entrance in the opposite direction of the natural flow (Pic 2). Halfway along its length the fishway turns 180˚ before reaching the Taylor Lake. To access the lake, fish must migrate through a square hole located in the bottom corner of the stop logs at the head of fishway (Milino pers. comm.).

Picture 2. Entrance to Kloiya River fishway.

In 2010, no migration was recorded until March 14. Migration was intermittent until early April when migration activity increased and became more consistent (Fig 6). Migration timing through the fishway was consistent with the timing recorded in 2006 and 2007 (Fig 7). Increase in migration activity coincided with increasing water temperatures (Fig 9). Since 2006, the data indicate that the majority of steelhead will migrate past the counter when water temperatures are increasing (Peard 2007; Peard 2008; Peard 2010). However, the water temperature that represents the highest proportional steelhead migration has ranged from 31.3% (5.00˚C to 5.99˚C) in 2006 to 41.0% (8.00˚C to 8.99˚C) in 2010.

Temp Range (Celsius)	Up count uncorrected for counter efficiency	%
0-0.99	0	0.00
1.00-1.99	0	0.00
2.00-2.99	0	0.00
3.00-3.99	3	2.15
4.00-4.99	15	10.79
5.00-5.99	21	15.11
6.00-6.99	9	6.52
7.00-7.99	7	5.03
8.00-8.99	57	41.00
9.00-9.99	4	2.87
Greater than 10	21	15.10
Total	139	100

Table 3. Table showing fishway activity related to water temperature.

5.0 Discussion

Prior to 2006, The Ministry of Environment did not have a winter-run steelhead index in the Skeena Region. The Kloiya River was investigated, as a possible winter-run index, due to its size and proximity to Prince Rupert and the Smithers Regional MoE office. It also provided the infrastructure to securely store the equipment while in operation, and the dam provided a potential opportunity to generate electrical power precluding the need to operate generators. Resistivity counter technology was selected as the enumeration method since the technology required limited maintenance, and the successful use of the technology to enumerate steelhead populations on the Keogh, Bonaparte and Deadman Rivers in British Columbia. The Kloiya River design was based on the tube type counter installed in a vertical slot fish way in the Bonaparte River.

In 2010, run timing and migration behaviour through the fishway was consistent with the results in 2006 and 2007. Since very limited migration was again observed through the fishway until the middle of March, installation of the counter in early March should be sufficient to capture the annual winter steelhead run in the Kloiya River.

One of the challenges of operating electronics in remote locations is securing a consistent source of electricity to keep the equipment powered up. For the last two years power has been supplied via a stream engine that utilizes the reservoir to provide power for the counter operations.

The goals and objectives in 2010 were met. The conclusion is that the goals and objectives of this project were achieved and continues to present a viable opportunity to enumerate winter-run steelhead on a annual basis and should be continued.

4.0 Recommendations

- Install a staff gauge in the fishway to record water levels.
- In future years, when abundance counts are below expectations, a snorkel swim in the two kilometre section of river below the dam may provide some indication of steelhead abundance below the fishway.
- Expand the scope of the project to incorporate genetic and life history information into the analysis.
- Investigate options for facilitating fish migration through the fishway.
- Annual snorkel surveys should be conducted immediately prior to the removal of the resistivity counter to estimate the number of steelhead spawning in the Kloiya River at that time.

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Appendix 1. Counter data

Date	Time		Channel	Description	P.S.S
10-Mar	10:36:02	100	2	E	127
10-Mar	10:36:08	100	2	E	115
10-Mar	11:39:29	100	2	E	127
10-Mar	11:39:30	100	2	E	126
10-Mar	11:39:32	100	2	E	127
10-Mar	11:39:34	100	2	E	127
10-Mar	13:17:54	100	2	E	18
10-Mar	13:18:04	100	2	E	40
10-Mar	13:18:08	100	2	E	75
14-Mar	18:14:06	100	2	U	45
14-Mar	19:49:23	100	2	D	127
16-Mar	14:44:42	100	2	U	40
16-Mar	22:45:55	100	2	D	27
17-Mar	7:03:59	100	2	E	27
19-Mar	14:24:03	100	2	U	46
20-Mar	1:00:36	100	2	U	61
20-Mar	1:24:45	100	2	D	111
20-Mar	13:02:17	100	2	U	46
22-Mar	0:58:55	100	2	U	126
22-Mar	1:12:58	100	2	E	127
22-Mar	1:53:55	100	2	D	103
22-Mar	4:57:11	100	2	U	52
22-Mar	5:41:19	100	2	D	126
23-Mar	3:59:20	100	2	D	27
23-Mar	12:14:52	100	2	U	38
24-Mar	15:31:11	100	2	U	59
24-Mar	15:46:31	100	2	D	127
26-Mar	13:13:01	100	2	U	71
29-Mar	16:21:50	100	2	U	49
29-Mar	16:48:09	100	2	U	91
29-Mar	16:54:02	100	2	U	46
29-Mar	17:05:19	100	2	U	42
30-Mar	11:46:13	100	2	U	38
30-Mar	11:46:44	100	2	U	46
30-Mar	11:46:46	100	2	D	47
30-Mar	14:13:05	100	2	U	79
30-Mar	14:13:11	100	2	D	125
30-Mar	14:13:14	100	2	U	56
31-Mar	2:52:41	100	2	E	32
31-Mar	23:18:29	100	2	D	49

01-Apr	20:57:33	100	2	E	30
02-Apr	14:53:26	100	2	U	47
01-Apr	15:05:15	100	2	U	52
02-Apr	15:13:29	100	2	E	125
03-Apr	15:42:22	100	2	U	56
03-Apr	18:39:52	100	2	U	74
03-Apr	23:42:20	100	2	D	57
04-Apr	15:09:06	100	2	U	48
05-Apr	15:49:40	100	2	D	67
05-Apr	18:43:33	100	2	U	56
05-Apr	19:01:41	100	2	U	26
05-Apr	19:01:45	100	2	E	56
05-Apr	19:47:04	100	2	D	63
05-Apr	22:18:12	100	2	E	83
05-Apr	23:59:14	100	2	U	60
06-Apr	1:16:07	100	2	D	127
06-Apr	1:19:11	100	2	D	36
06-Apr	10:48:35	100	2	U	55
06-Apr	16:11:11	100	2	E	27
06-Apr	17:05:40	100	2	U	96
06-Apr	17:09:16	100	2	E	127
06-Apr	17:59:56	100	2	U	55
06-Apr	21:00:13	100	2	U	127
06-Apr	21:00:17	100	2	E	38
06-Apr	21:34:19	100	2	E	26
06-Apr	21:34:31	100	2	E	127
06-Apr	21:40:24	100	2	D	127
06-Apr	21:53:03	100	2	E	39
07-Apr	0:05:20	100	2	U	125
07-Apr	0:31:35	100	2	U	77
07-Apr	2:06:11	100	2	U	58
07-Apr	2:06:16	100	2	E	29
07-Apr	11:29:31	100	2	E	43
07-Apr	19:13:50	100	2	U	119
07-Apr	22:11:55	100	2	E	50
08-Apr	14:51:08	100	2	U	55
08-Apr	14:51:14	100	2	E	86
08-Apr	15:18:22	100	2	U	54
08-Apr	19:08:10	100	2	E	48
08-Apr	20:42:1	3 10	2	D	26
08-Apr	22:39:18	100	2	E	43
09-Apr	14:58:20	100	2	U	56
10-Apr	4:06:32	100	2	E	26

10-Apr	22:17:12	100	2	U	52
10-Apr	22:17:14	100	2	E	34
10-Apr	22:17:16	100	2	E	62
10-Apr	22:38:37	100	2	U	126
11-Apr	1:53:14	100	2	E	125
11-Apr	1:53:17	100	2	D	107
11-Apr	2:24:20	100	2	U	127
11-Apr	12:07:25	100	2	U	41
12-Apr	0:30:02	100	2	D	27
12-Apr	1:03:26	100	2	U	127
12-Apr	1:08:51	100	2	U	127
12-Apr	1:08:55	100	2	D	127
12-Apr	1:30:44	100	2	U	77
12-Apr	3:23:33	100	2	U	56
12-Apr	3:31:24	100	2	D	126
12-Apr	3:36:45	100	2	U	68
13-Apr	0:23:55	100	2	D	27
13-Apr	0:56:00	100	2	U	127
13-Apr	5:50:52	100	2	U	81
13-Apr	15:42:13	100	2	E	61
13-Apr	16:06:08	100	2	E	80
13-Apr	16:06:09	100	2	E	79
13-Apr	16:06:10	100	2	E	62
13-Apr	16:06:11	100	2	E	45
13-Apr	16:13:25	100	2	E	127
13-Apr	21:03:13	100	2	D	37
13-Apr	23:56:52	100	2	E	55
14-Apr	15:02:09	100	2	E	97
14-Apr	15:02:10	100	2	E	81
14-Apr	15:02:13	100	2	E	125
14-Apr	18:59:41	100	2	E	74
14-Apr	22:33:49	100	2	D	30
14-Apr	22:36:13	100	2	D	27
15-Apr	0:01:37	100	2	E	29
15-Apr	1:16:53	100	2	D	38
15-Apr	2:16:32	100	2	E	87
15-Apr	6:07:43	100	2	E	127
15-Apr	14:18:38	100	2	U	42
15-Apr	21:09:47	100	2	D	52
16-Apr	2:23:24	100	2	E	114
16-Apr	2:49:31	100	2	E	127
16-Apr	8:16:57	100	2	U	51
16-Apr	10:52:43	100	2	U	56

16-Apr	22:36:46	100	2	E	124
16-Apr	23:04:40	100	2	D	80
17-Apr	0:23:05	100	2	U	71
17-Apr	6:59:33	100	2	U	68
17-Apr	23:50:37	100	2	E	125
18-Apr	0:44:37	100	2	D	127
18-Apr	2:47:46	100	2	E	26
18-Apr	2:54:20	100	2	U	127
18-Apr	3:16:11	100	2	E	127
18-Apr	3:16:23	100	2	E	29
18-Apr	4:03:07	100	2	D	82
18-Apr	11:32:24	100	2	U	43
18-Apr	12:18:42	100	2	E	107
18-Apr	13:03:59	100	2	U	58
18-Apr	13:05:26	100	2	D	64
18-Apr	14:05:41	100	2	U	49
18-Apr	15:51:56	100	2	U	47
18-Apr	15:57:51	100	2	U	62
18-Apr	16:06:13	100	2	U	44
18-Apr	16:14:30	100	2	U	53
18-Apr	16:19:38	100	2	U	47
18-Apr	16:37:10	100	2	U	57
18-Apr	17:04:47	100	2	E	115
19-Apr	5:49:34	100	2	U	64
19-Apr	21:11:54	100	2	D	28
19-Apr	22:09:33	100	2	U	107
19-Apr	23:19:16	100	2	D	123
20-Apr	0:15:04	100	2	U	127
20-Apr	0:44:29	100	2	D	32
20-Apr	6:27:06	100	2	U	72
20-Apr	6:40:34	100	2	U	119
20-Apr	7:42:14	100	2	E	127
20-Apr	9:14:26	100	2	U	43
20-Apr	11:05:28	100	2	D	59
20-Apr	11:34:26	100	2	U	50
20-Apr	14:17:49	100	2	E	125
20-Apr	15:15:45	100	2	D	50
20-Apr	16:14:19	100	2	U	62
20-Apr	19:51:22	100	2	D	115
20-Apr	21:51:02	100	2	D	31
20-Apr	21:52:38	100	2	E	127
20-Apr	22:02:49	100	2	D	45
20-Apr	22:32:49	100	2	U	55

21-Apr	0:05:10	100	2	D	79
21-Apr	0:58:22	100	2	D	29
21-Apr	1:48:37	100	2	E	33
21-Apr	13:59:34	100	2	E	122
21-Apr	16:55:38	100	2	U	89
21-Apr	21:51:56	100	2	E	33
21-Apr	22:15:33	100	2	D	54
21-Apr	22:59:56	100	2	E	33
22-Apr	0:12:46	100	2	E	42
22-Apr	5:34:59	100	2	D	26
22-Apr	10:57:50	100	2	D	60
22-Apr	13:10:45	100	2	U	64
22-Apr	15:04:17	100	2	U	57
22-Apr	17:19:14	100	2	E	26
22-Apr	19:49:23	100	2	U	80
22-Apr	22:11:35	100	2	E	27
23-Apr	1:35:41	100	2	U	72
23-Apr	1:35:44	100	2	D	127
23-Apr	3:05:39	100	2	E	36
23-Apr	9:02:13	100	2	U	54
23-Apr	9:02:17	100	2	E	51
23-Apr	9:02:19	100	2	E	70
23-Apr	9:02:23	100	2	D	112
23-Apr	10:47:25	100	2	E	127
23-Apr	10:54:51	100	2	U	58
23-Apr	10:58:25	100	2	U	57
23-Apr	13:53:20	100	2	E	117
23-Apr	17:47:10	100	2	U	40
23-Apr	18:36:34	100	2	U	63
23-Apr	22:09:15	100	2	U	127
24-Apr	0:03:28	100	2	U	127
24-Apr	0:04:43	100	2	D	127
24-Apr	0:06:13	100	2	E	119
24-Apr	0:06:16	100	2	E	38
24-Apr	12:54:44	100	2	U	57
24-Apr	22:49:55	100	2	E	29
24-Apr	23:17:04	100	2	D	65
25-Apr	1:12:06	100	2	U	99
25-Apr	3:05:52	100	2	E	28
25-Apr	5:05:06	100	2	D	36
25-Apr	8:20:43	100	2	D	74
25-Apr	21:20:19	100	2	E	26
25-Apr	22:50:33	100	2	E	27

25-Apr	23:35:04	100	2	D	28
26-Apr	0:54:15	100	2	U	85
26-Apr	1:50:07	100	2	D	58
26-Apr	6:41:22	100	2	E	27
26-Apr	14:18:54	100	2	D	127
26-Apr	17:26:18	100	2	U	54
27-Apr	0:54:19	100	2	U	55
27-Apr	1:01:17	100	2	U	77
27-Apr	3:32:32	100	2	U	95
27-Apr	7:12:08	100	2	D	127
27-Apr	14:30:39	100	2	D	30
27-Apr	18:34:14	100	2	U	67
27-Apr	18:56:21	100	2	D	58
27-Apr	23:02:51	100	2	E	30
28-Apr	1:57:59	100	2	U	55
28-Apr	6:17:03	100	2	E	91
29-Apr	0:53:14	100	2	D	35
29-Apr	1:12:16	100	2	D	29
29-Apr	2:44:00	100	2	D	34
29-Apr	4:08:18	100	2	U	105
29-Apr	8:45:32	100	2	E	31
29-Apr	18:19:07	100	2	U	110
30-Apr	2:07:18	100	2	E	33
30-Apr	5:05:12	100	2	U	124
30-Apr	6:20:58	100	2	U	127
30-Apr	11:57:04	100	2	E	125
30-Apr	21:37:22	100	2	E	36
01-May	1:38:10	100	2	U	125
01-May	10:30:46	100	2	U	67
01-May	21:09:40	100	2	E	26
01-May	21:23:24	100	2	D	28
02-May	17:07:49	100	2	E	125
02-May	17:33:3	100	2	U	52
02-May	22:20:59	100	2	U	59
03-May	7:12:16	100	2	U	55
03-May	12:13:32	100	2	E	41
03-May	13:19:08	100	2	D	36
03-May	15:20:23	100	2	U	55
04-May	4:43:16	100	2	E	125
04-May	4:43:20	100	2	D	127
04-May	6:20:04	100	2	E	122
04-May	10:17:10	100	2	D	125
04-May	16:06:39	100	2	U	50

04-May	18:06:36	100	2	U	71
04-May	22:04:42	100	2	U	127
04-May	22:27:32	100	2	U	65
04-May	23:32:12	100	2	E	26
04-May	23:53:23	100	2	U	67
05-May	14:58:55	100	2	U	49
05-May	15:09:53	100	2	U	50
05-May	15:46:16	100	2	U	51
05-May	15:47:51	100	2	E	26
05-May	15:48:40	100	2	D	78
06-May	2:14:20	100	2	U	127
06-May	2:16:45	100	2	U	60
06-May	5:54:38	100	2	U	90
06-May	12:32:57	100	2	U	58
06-May	19:54:41	100	2	D	111
06-May	22:42:41	100	2	E	27
06-May	23:11:52	100	2	E	35
07-May	1:01:09	100	2	U	127
07-May	8:02:55	100	2	D	127
07-May	8:08:49	100	2	D	112
07-May	13:00:05	100	2	D	125
07-May	15:36:42	100	2	U	48
07-May	19:36:24	100	2	D	32
08-May	0:47:26	100	2	U	125
08-May	2:04:15	100	2	E	30
08-May	10:58:22	100	2	E	82
08-May	16:16:58	100	2	D	60
09-May	10:30:04	100	2	E	127
09-May	11:00:09	100	2	D	98
10-May	7:23:17	100	2	U	63
10-May	10:01:30	100	2	D	125
10-May	14:26:59	100	2	U	52
10-May	14:28:51	100	2	D	79
10-May	16:28:35	100	2	U	48
10-May	18:29:47	100	2	U	57
11-May	1:17:36	100	2	U	74
11-May	4:32:24	100	2	E	30
11-May	6:15:24	100	2	U	115
11-May	8:05:16	100	2	E	127
11-May	13:23:39	100	2	D	65
11-May	17:48:07	100	2	U	56
13-May	2:35:37	100	2	D	67
13-May	13:44:29	100	2	D	45

13-May	15:49:49	100	2	D	60
14-May	12:45:41	100	2	D	80
14-May	15:36:28	100	2	U	48
14-May	17:19:14	100	2	D	39
15-May	3:01:18	100	2	U	83
15-May	3:53:29	100	2	U	127
15-May	4:06:02	100	2	E	125
15-May	4:53:55	100	2	U	125
15-May	15:01:59	100	2	D	125
16-May	0:03:48	100	2	E	127
16-May	6:59:44	100	2	U	54
16-May	14:53:04	100	2	D	70
17-May	6:22:03	100	2	U	59
17-May	8:56:43	100	2	D	42
17-May	10:09:39	100	2	E	51
17-May	13:10:26	100	2	U	90
17-May	17:17:03	100	2	U	58
18-May	4:04:38	100	2	U	127
18-May	6:51:02	100	2	U	26
18-May	16:31:06	100	2	U	61
18-May	23:31:47	100	2	E	30
18-May	23:32:42	100	2	D	56
19-May	0:00:55	100	2	U	127
19-May	0:12:14	100	2	E	46
19-May	11:09:27	100	2	E	36
20-May	0:49:31	100	2	U	127
20-May	4:39:15	100	2	U	127

Appendix 2. Daily Mean Water Temperatures

Date	Temp˚C
10-Mar	3.72
11-Mar	3.67
12-Mar	3.66
13-Mar	3.60
14-Mar	3.68
15-Mar	3.78
16-Mar	3.83
17-Mar	3.88
18-Mar	3.89
19-Mar	3.96
20-Mar	4.08
21-Mar	4.36
22-Mar	4.55
23-Mar	4.58
24-Mar	4.61
25-Mar	4.68
26-Mar	4.80
27-Mar	4.84
28-Mar	4.84
29-Mar	4.87
30-Mar	4.95
31-Mar	5.15
01-Apr	5.28
02-Apr	5.30
03-Apr	5.43
04-Apr	5.60
05-Apr	5.85
06-Apr	5.94
07-Apr	5.74
08-Apr	5.41
09-Apr	5.56
10-Apr	5.78
11-Apr	6.11
12-Apr	6.39
13-Apr	6.50
14-Apr	6.64
15-Apr	7.25
16-Apr	7.54
17-Apr	7.83

18-Apr	8.28
19-Apr	8.27
20-Apr	8.13
21-Apr	8.27
22-Apr	8.32
23-Apr	8.07
24-Apr	8.26
25-Apr	8.34
26-Apr	8.40
27-Apr	8.47
28-Apr	8.67
29-Apr	8.91
30-Apr	8.84
01-May	8.50
02-May	7.99
03-May	8.16
04-May	8.52
05-May	8.93
06-May	9.33
07-May	9.72
08-May	10.34
09-May	10.79
10-May	10.79
11-May	11.07
12-May	11.00
13-May	11.56
14-May	11.94
15-May	12.00
16-May	12.53
17-May	12.87
18-May	13.02
19-May	12.86
20-May	12.01