Results of the Kloiya River Resistivity Counter 2007

Skeena Fisheries Report SK 154

Dean Peard[1]
August 2008

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

Executive Summary

A Logie 2100C resistivity counter was installed at the Kloiya River on January 19, 2007. 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 the vertical slot fishway. A Capture Digital Video Recorder, in combination with a 37CHR-IR Nightview underwater camera, was used to confirm species identification. 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. The DVR was triggered by the counter to record a digital image five seconds before and five seconds after a change in conductivity was detected by the counter. A row of data for each event was comprised of the date, time, direction of travel and peak signal strength. Trace data was collected on a Toshiba laptop computer. Electrical power was provided by a gasoline powered Honda generator for the duration of the project. Hourly water and air temperatures were collected on Optic Stowaway temperature data loggers during the project. The lowest mean daily water temperature recorded was 1.48°C on January 19, 20 and 21 respectively. The highest mean daily water temperature was 8.28°C on May 13.

The first fish was recorded on March 8, 2007. There was very limited steelhead migration through the fishway until early April. Increased activity appeared to coincide with warmer water temperatures. The majority (95%) of the upstream migrants were recorded between April 6 and May 13. The highest daily upstream count was 8 on April 24.Trace data was recorded for 74% of the events recorded by counter. Trace data indicates that the counter efficiency for upstream migrants was 94% and 76% for downstream migrants. The steelhead escapement, upstream of the Kloiya River dam is estimated to be 75. The counter was pulled two weeks prior to the removal date from 2006. The crew who were monitoring and charging the batteries were not available to continue after this date.

Table of Contents

List of Figures

List of Tables

List of Pictures

List of Appendices

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 project in 2006. The 1981 study was limited to quantifying juvenile steelhead abundance 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 and 2007.

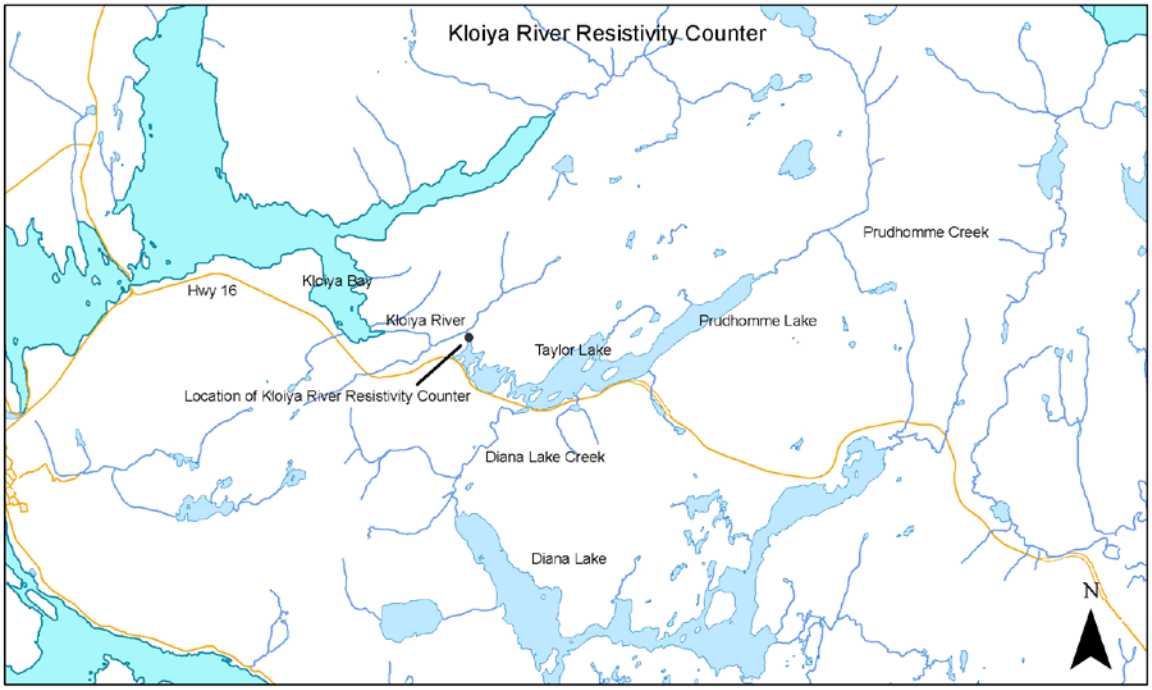

Figure 1. Location of Kloiya River resistivity counter.

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 resistance of the water within the field. The counter recalibrates the measured resistance every 30 minutes. When a fish passes through the field the change in resistance 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 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 2007, trace data, produced by the Logie 21000 C, was captured on a Toshiba laptop computer. Trace and count data was downloaded weekly. Three Optic Stowaway temperature data loggers (*Onset Computer Corporation, Pocasset, MA*) recorded hourly temperature (°C) One data logger recorded ambient air temperature, and the other two were located in the fishway and Taylor Lake respectively.

A Capture Digital Video Recorder (*Solid State Devices Incorporated, La Miranda CA*.) was utilized to capture digital images of fish migrating through the counter tube. The DVR was connected to a underwater colour camera that was attached to the downstream side of the counter tube. Digital images were captured to identify species utilizing the fishway during the project.

Electrical power for the counter system was generated by a Honda gasoline powered generator. The generator was operated every 48 hours to charge the batteries and keep the equipment powered.

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. Increasing the counter gain may increase counter efficiency. Threshold values required for fish identification was set at 20. Counter software used during the 2007 project was version 9.10.

3.2 DVR Settings

The DVR was set to record images five seconds before and after the counter was triggered by a change in conductivity within the counter field.

4.0 Results

4.1 Counter Efficiency

The Kloiya River resistivity counter was installed and operational on January 19, 2007. The first fish was recorded on March 8, 2007 and the last fish was recorded on May 13, 2007. During this time period, the counter recorded 100 up counts, 24 down counts and 31 events. Events indicate a change in conductivity that was not recognized by the counter algorithm as a fish. A total of 155 rows of data were recorded as upstream counts, downstream counts and events (Table1).

Date	Time	Description of Event	P.S.S
09-Apr-07	15:56:40	U	51
09-Apr-07	16:48:26	D	117
09-Apr-07	16:54:39	U	44
09-Apr-07	16:54:49	D	127
09-Apr-07	17:04:06	U	50
09-Apr-07	17:04:15	E	80
09-Apr-07	17:04:18	E	127
09-Apr-07	17:16:35	E	122
10-Apr-07	13:05:09	U	48
10-Apr-07	13:20:23	U	55
11-Apr-07	16:55:18	U	40
14-Apr-07	9:36:10	U	34
14-Apr-07	10:40:48	U	43
14-Apr-07	11:36:39	U	42
14-Apr-07	11:47:13	U	43
14-Apr-07	11:55:01	U	47

Table 1**.** Example of text data collected from counter in 2007**.**

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. 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.

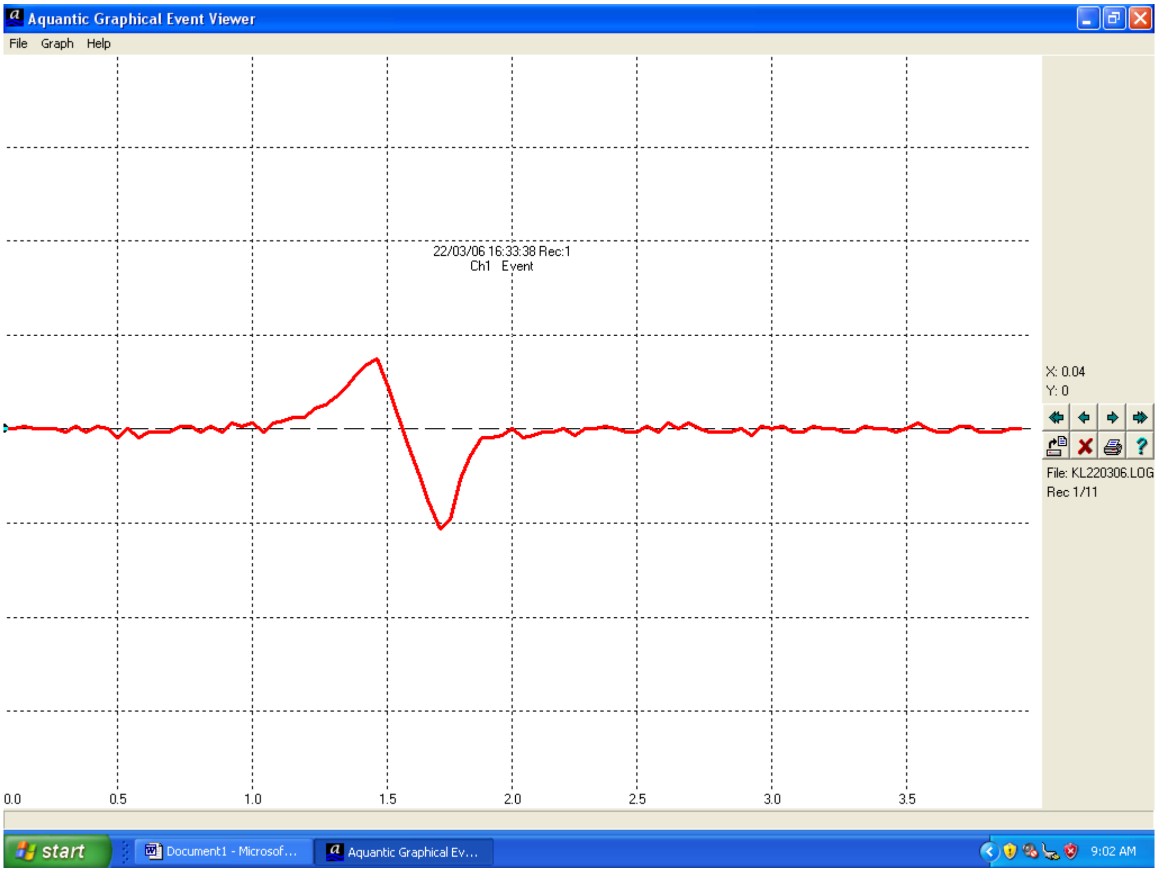

Figure 2. Downstream migrant incorrectly classified as a non fish event.

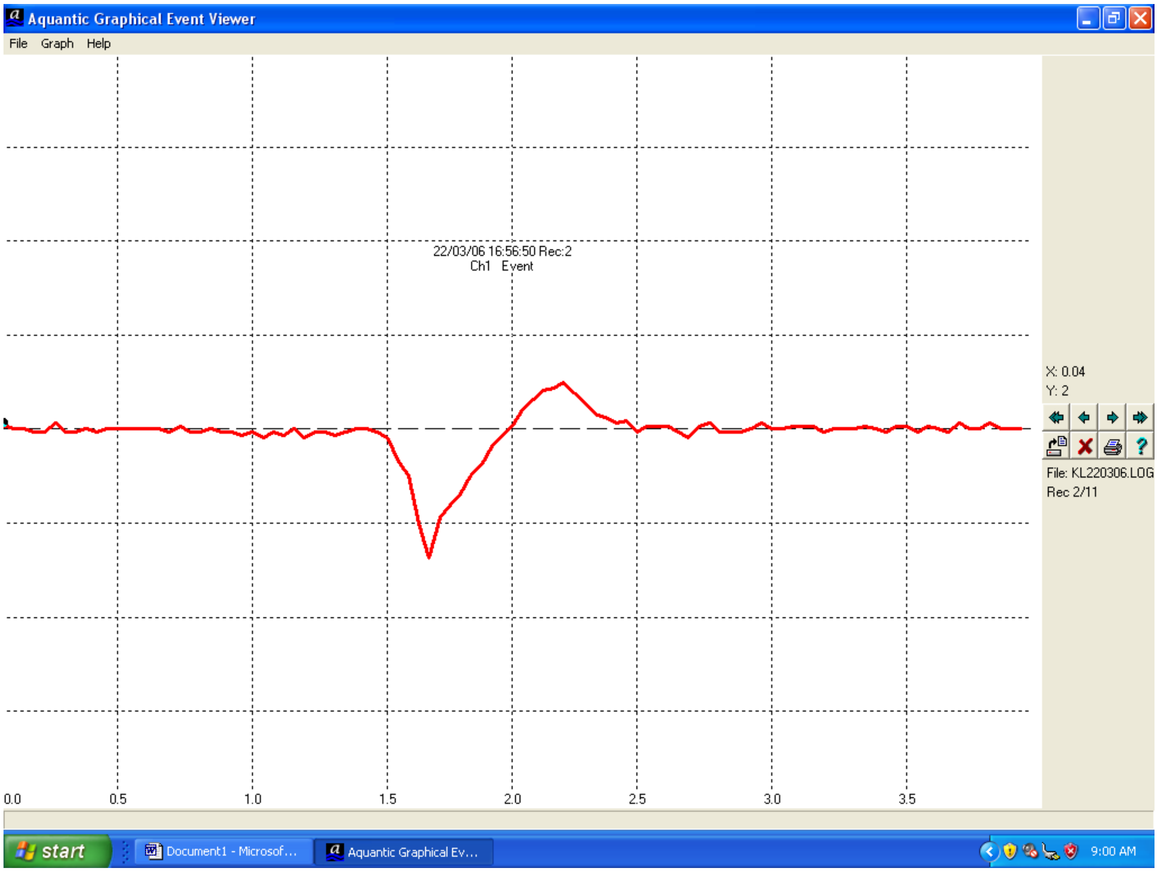

Figure 3. Upstream migrant incorrectly classified as a non fish event.

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.

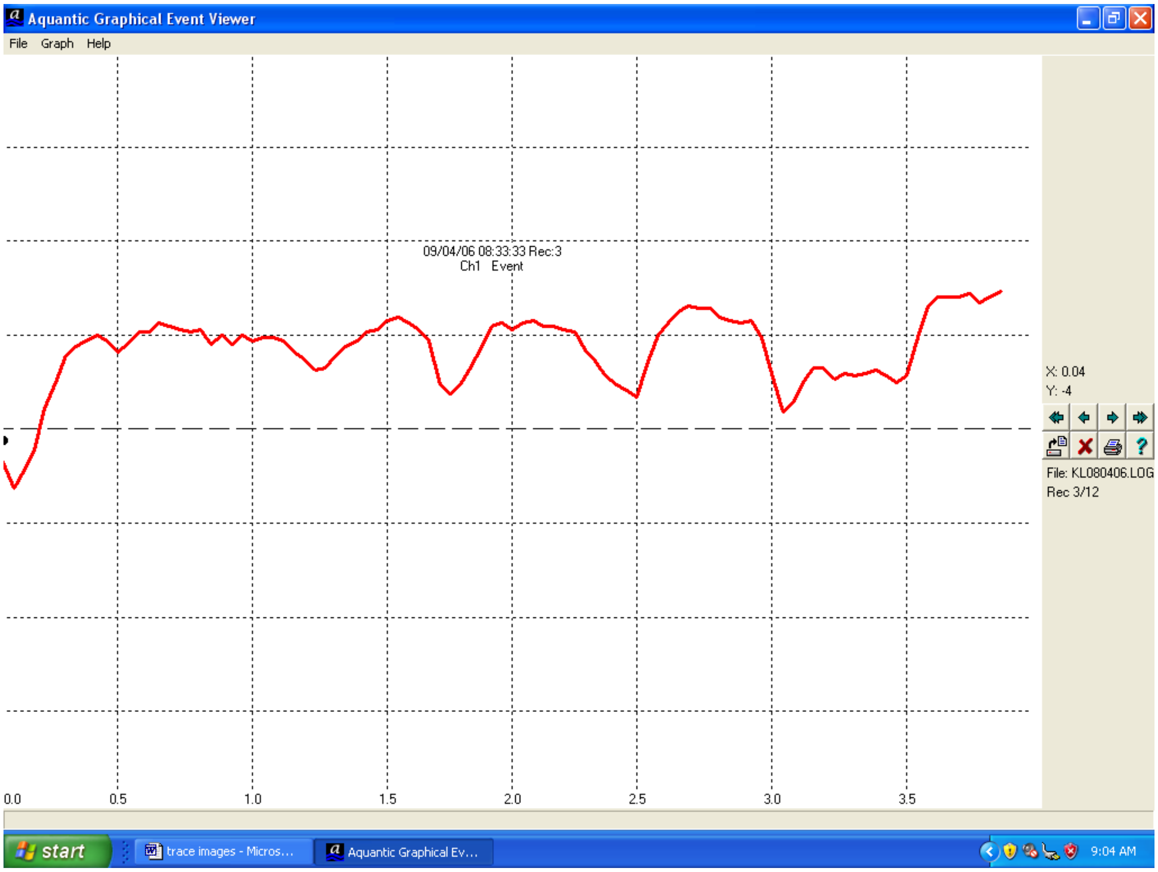

Figure 4. Change in conductivity correctly classified as a non fish event.

4.2 Digital Video Results

A total of 74 images were recorded during the 2007 project. Image quality was dependant on light and flow conditions. Images recorded during low light and high flow conditions were poor. Nearly half of the images collected 36 (48%) were very poor quality and fish identification could not be determined. All except for two of the remaining images (otter) indicated that steelhead were the only species being recorded by the counter.

Video Description	**Count**
No image recorded	81
No Fish Observed (poor image)	33
Otter	2
Steelhead upstream	30
Steelhead downstream	8
Steelhead up and down	1

Table 3. Classification of digital video data

A river otter was recorded and observed by the counter on May 2 and May 3. The counter correctly classified the event as a non-fish migration. The trace pattern for the otter was atypical for a fish trace and would never meet the algorithm's thresholds to be classified as a fish.

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 analysis 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 remaining events where trace data does not exist. There are 11 logged events where trace data does not exist. To estimate up counts, 11 is multiplied by 0.22. Therefore, it is estimated that 2 upstream migrants were not correctly classified. The estimate for downstream migrants is 11 multiplied by 0.30. It is estimated that 3 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.

U+UE-D+DE=escapement (100+2)- (24+3) = 75

The counter was removed two weeks earlier than 2006. The crew monitoring the equipment and charging the batteries were unable to continue after May 13. In 2006, 15% (n=21) of the upstream counts occurred between May 14 and May 26. Therefore, the 2007 escapement estimate is likely low. Figure 5 shows the escapement estimates for 2006 and 2007.

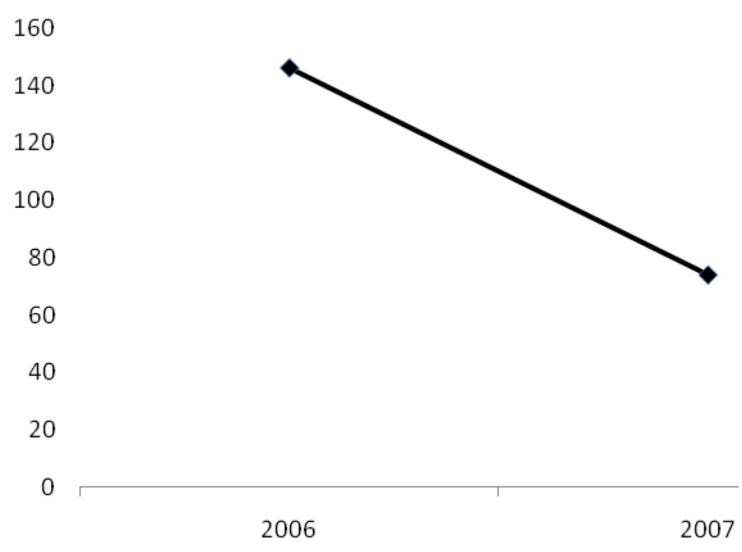

Figure 5. Kloiya River steelhead escapement estimates 2006 and 2007

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).* The counter was installed and operational on January 19, 2007. Information from anglers suggested that there are typically steehead present below the Kloiya Dam in December, January and February. However, the first steelhead recorded by the counter occurred on March 8. 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. Although the counter was operational from January 19, 2007 to May 13 ,2007 there were no counts recorded until March 8, 2007. Between March 1 and April 3, 5% of the steelhead recorded migrated into Taylor Lake. Daily counts, during this time period, ranged from zero to one. Between April 4 and May 26, 95% of the upstream migrants were recorded. Daily upstream migrations in this time period ranged between zero and eight. The peak daily upstream count occurred on April 24 (Fig 6).

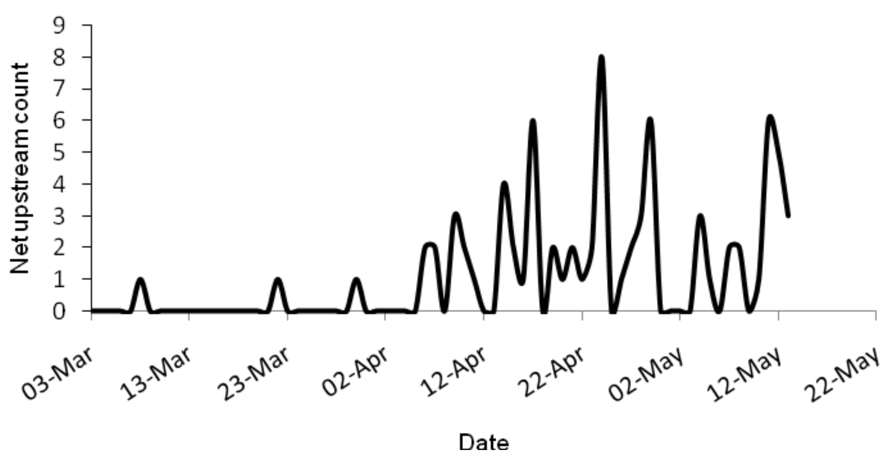

Figure 6 Uncorrected net daily up counts March 1 to May 26, 2007.

Run timing in 2007 was comparable to run timing in 2006. 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).

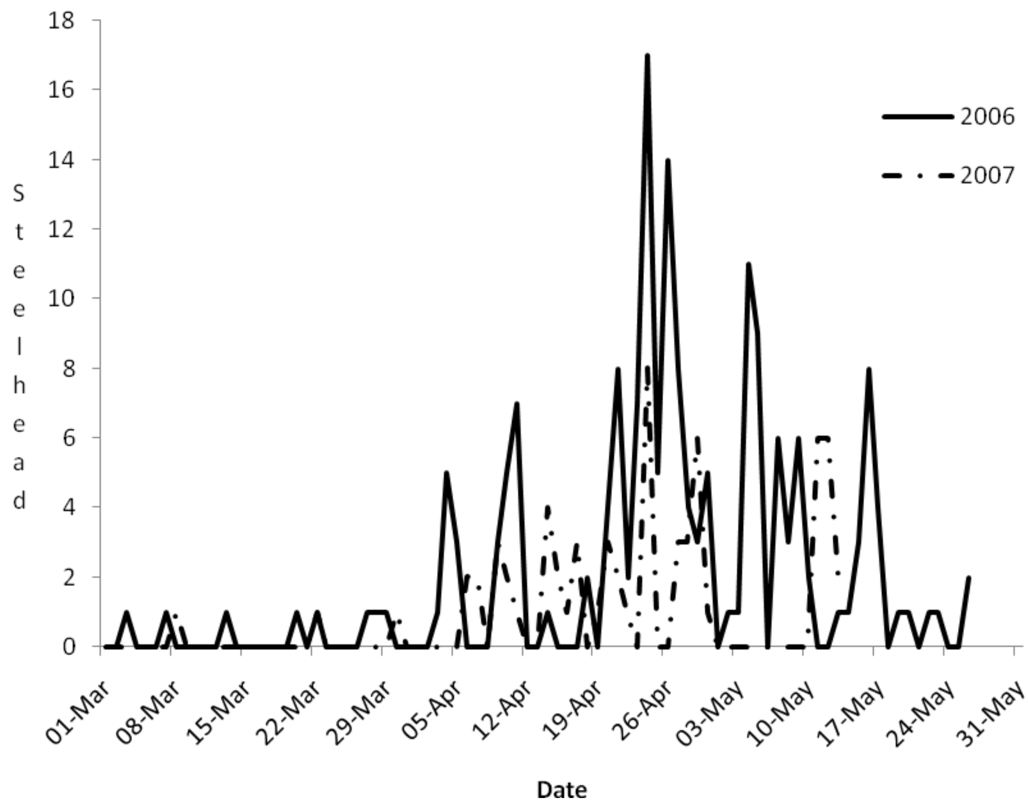

Figure 7. Kloiya River steelhead run timing 2006 and 2007.

4.5 Environmental Parameters

Hourly water temperatures were recorded by Optic Stowaway temperature data loggers. Water temperatures were recorded between January 19, 2007 and May 13, 2007. Water temperature ranged between 1.48˚C (Jan 19, 20, 21) and 8.28˚C (May 13). Mean water temperature for the duration of the 2007 project is 3.40˚C (SD=1.85) (Fig 8). The water temperature profiles for the two project years show a similar pattern (Fig 9). Maximum differences between hourly temperatures in a 24 hour period ranged between 0.14˚C (Feb 14) and 2.31˚C (April 4). The greatest daily water temperature variation, between years, occurred in early April. The daily temperature variation between 2006 and 2007 ranged from 1.18˚C and 2.31˚C from April 1 to April 16 (Fig 9).

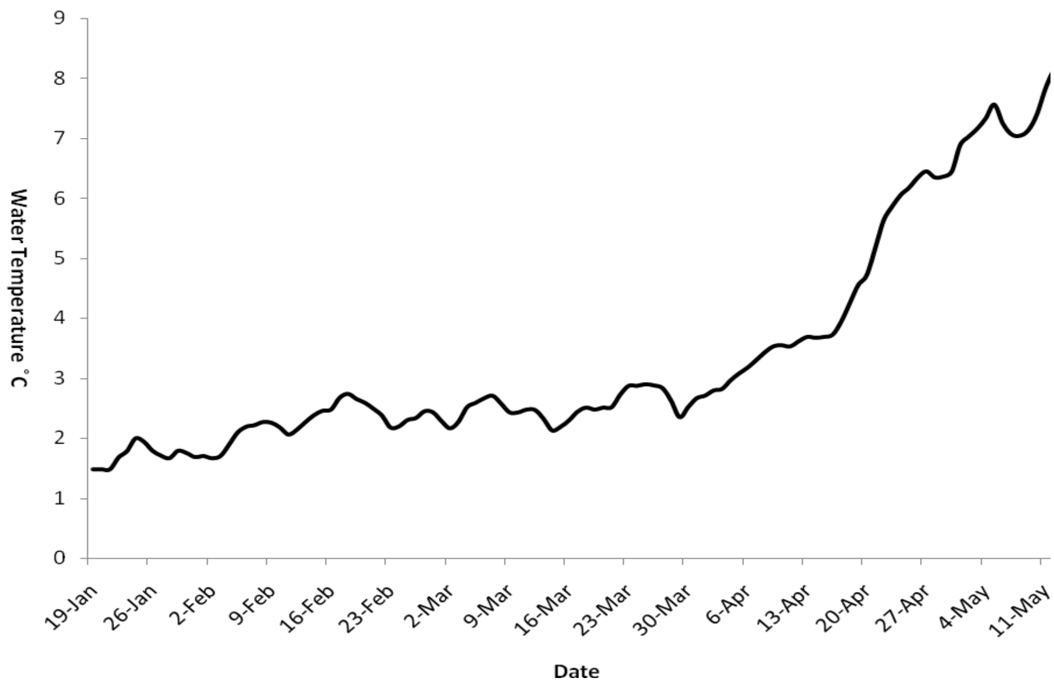

Figure 8 Mean daily water temperatures Kloiya River 2007.

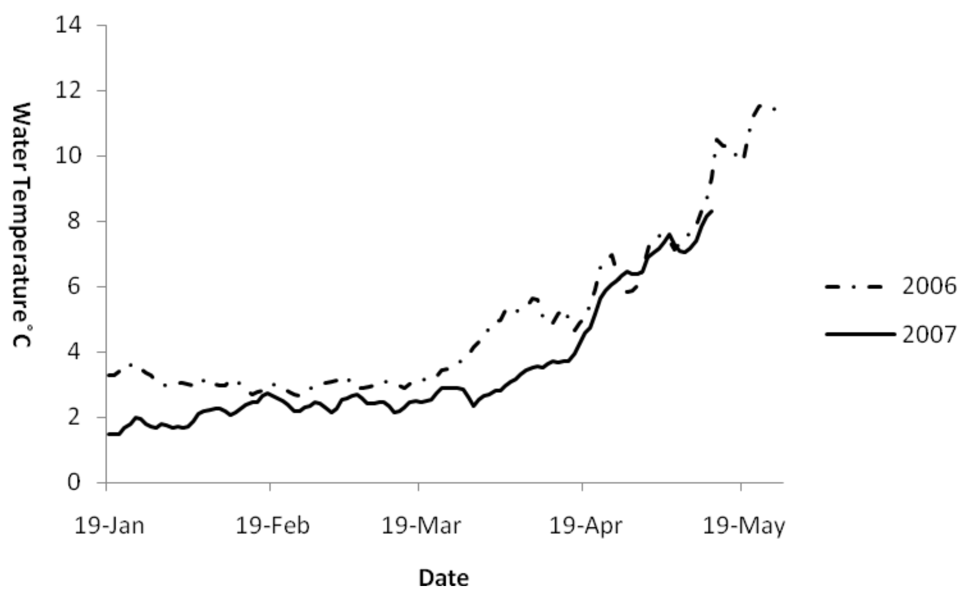

Figure 9. Daily water temperatures 2006, 2007

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 the 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.

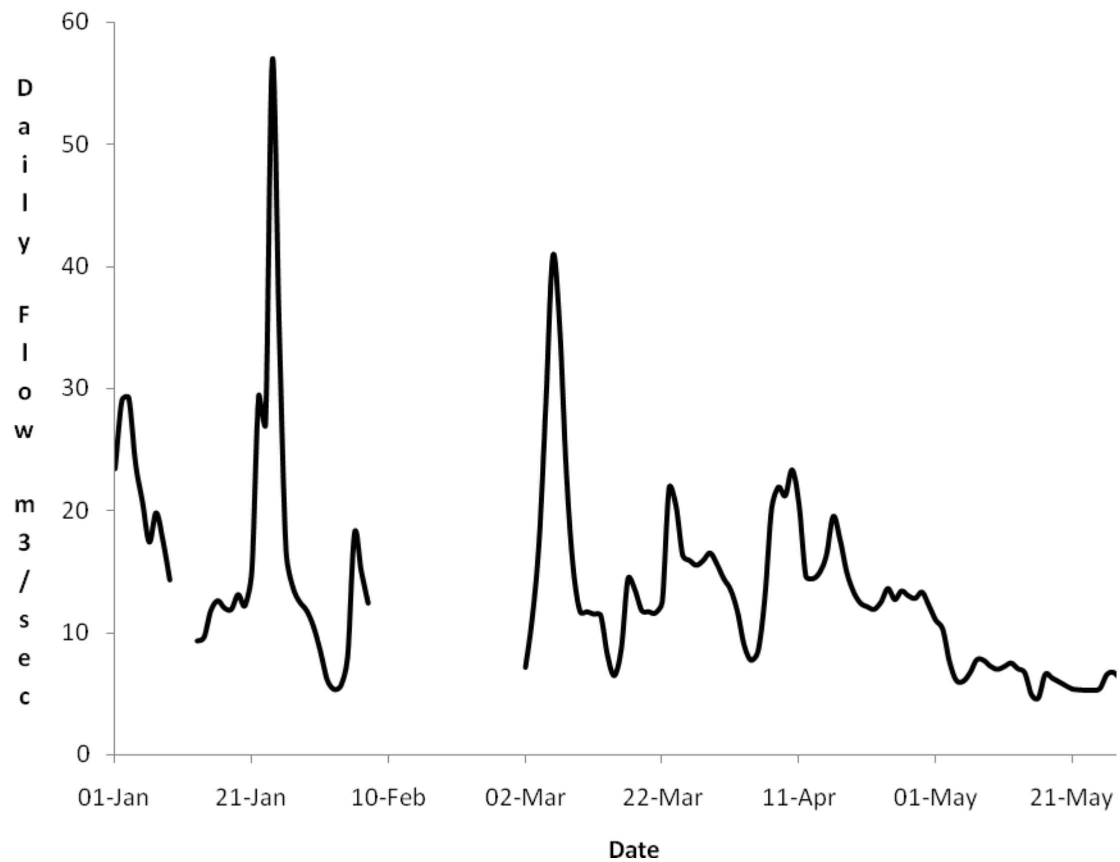

Figure 10 Mean daily flow (m³/sec) in the Kloiya River January 1 May 31 2007 (Env Canada survey station Kloiya River).

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 2007, no migration was recorded until March 8. Migration was intermittent until early April when migration activity increased and became more consistent (Fig 7). Migration timing through the fishway was consistent with the timing recorded in 2006 (Fig 7). Increase in migration activity coincided with increasing water temperatures (Fig 9). Further analysis indicates that water temperature exceeding 3˚C coincided with increased activity in the fishway. In 2006, 87% of up counts occurred when water temperatures were over 5˚C (Peard 2007). During the 2007project, 96% of all net up counts were recorded when water temperatures were greater than 3˚C (Table 3). In comparison, in 2007, only 63% of the migration occurred at water temperatures above 5˚C.The number of project days when daily water temperature fit these criteria is equal to 30 days. Water temperature was collected for 114 project days indicating that a majority of the upstream migrations occur over a short period of time.

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	4	3.77
3.00-3.99	28	26.4
4.00-4.99	7	6.60
5.00-5.99	5	4.7
6.00-6.99	33	31.13
7.00-7.99	19	17.92
8.00-8.99	10	9.43
9.00-9.99	0	0.00
Greater than 10	0	0.00
Total	106	100

Table 4. Table showing fishway activity related to water temperature.

The 50% migration date remained consistent between years despite the fact that the 2007 project was discontinued two weeks earlier. The 50% migration date was April 26 in 2006 and April 24 in 2007 (Fig 11). The 50% migration date was relatively consistent considering the 2007 escapement estimate is roughly half of the estimate in 2006.

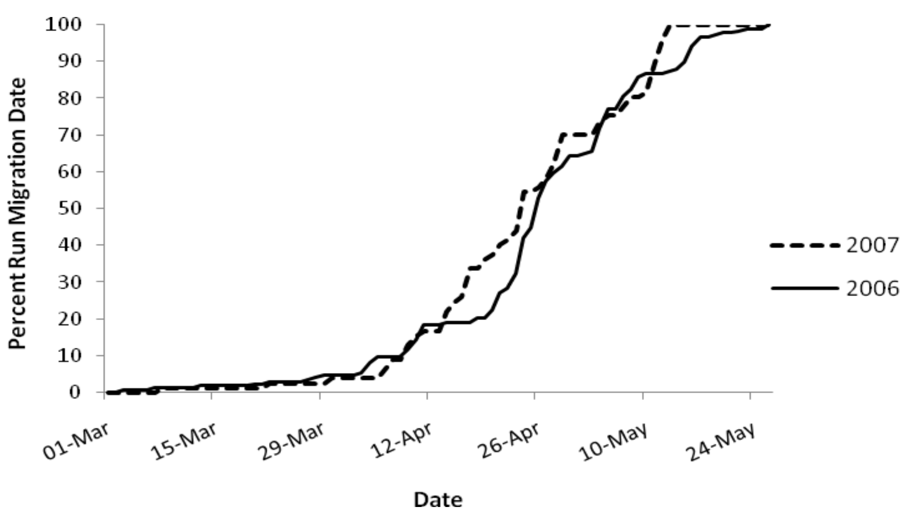

Figure 11. Cumulative proportional escapement migration date 2006 and 2007.

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 it's 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 2007, run timing and migration behaviour through the fishway was consistent with the results in 2006. 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.

This year was the first year of the implementation of the Steelhead Stream Classification Policy which precludes the harvest of wild steelhead by recreational anglers in British Columbia. Prior to the implementation of this policy there was limited wild steelhead harvest opportunities on the Kloiya River. Since there is only one year's escapement data prior to the implementation of the policy, and the relatively small annual winter-run steelhead escapement it will likely be difficult to detect changes in abundance related to the policy.

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 mechanical generator operated by Prince Rupert residents. In future years a more suitable method of power generation will have to be developed to reduce the maintenance required at the site.

The goals and objectives in 2007 were met and increasing the gain settings on the counter increased the counter efficiency. The digital underwater camera did provide some images to be analyzed, however, image quality was variable and dependant on turbidity and other hydrological conditions. 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

- Investigate other options to generate electrical power for counter operation.

- Investigate options for facilitating fish migration through the fishway.

References

Environment Canada .Water survey stations. http://scitech.pyr.ec.gc.ca/waterweb/formnav.asp

Habitat Wizard. Retrieved August 15, 2007, from *http://www.env.gov.bc.ca/habwiz/*

McCubbing, D.J.F. (2003). *Fish Counter Enumeration of steelhead and rainbow trout on the Bonaparte River in 2003-Post Fishway Redesign and Operational Improvements. Instream Fisheries Consultants.* Vancouver B.C.

Peard, D.P. (2007) *Results of the Kloiya River Resistivity Counter 2006. Ministry of Environment. Smithers* B.C.

Tredger, C.D. (1981). *Natural Rearing Capacity of the Kloiya River System, Near Prince Rupert, B.C. With Reference to the Kloiya River Community Development Program under S.E.P. Ministry of Environment.* Victoria, B.C.

Appendix 1. Counter data

Date	Time	Description	Peak Signal Strength	Trace Data	Trace Description
22-Feb-07	12:59:35	E	113	Yes	EE
22-Feb-07	22:16:00	E	38	Yes	EE
22-Feb-07	22:16:38	E	27	Yes	EE
03-Mar-07	10:04:06	E	12	No	NT
08-Mar-07	18:45:17	U	127	Yes	UU
10-Mar-07	4:15:47	E	27	Yes	EE
10-Mar-07	4:21:54	E	16	Yes	EE
12-Mar-07	3:01:58	E	26	No	NT
22-Mar-07	13:59:10	U	40	Yes	UU
30-Mar-07	15:31:04	U	51	Yes	UU
30-Mar-07	16:36:59	U	60	Yes	UU
30-Mar-07	16:38:05	D	34	Yes	DD
06-Apr-07	7:11:56	U	102	Yes	UU
06-Apr-07	7:11:59	E	127	Yes	EE
06-Apr-07	7:12:07	E	77	Yes	EE
06-Apr-07	16:41:43	U	42	Yes	UU
06-Apr-07	23:15:43	E	26	Yes	EE
07-Apr-07	16:01:23	U	44	Yes	UU
07-Apr-07	16:14:21	U	47	Yes	UU
09-Apr-07	14:49:15	U	63	Yes	UU
09-Apr-07	15:51:29	U	38	Yes	UU
09-Apr-07	15:56:40	U	51	Yes	UU
09-Apr-07	16:48:26	D	117	Yes	DD
09-Apr-07	16:54:39	U	44	Yes	UU
09-Apr-07	16:54:49	D	127	Yes	DD
09-Apr-07	17:04:06	U	50	Yes	UU
09-Apr-07	17:04:15	E	80	Yes	DE
09-Apr-07	17:04:18	E	127	Yes	EE
09-Apr-07	17:16:35	E	122	Yes	UE
10-Apr-07	13:05:09	U	48	Yes	UU
10-Apr-07	13:20:23	U	55	Yes	UU
11-Apr-07	16:55:18	U	40	Yes	UU
14-Apr-07	9:36:10	U	34	Yes	UU
14-Apr-07	10:40:48	U	43	Yes	UU
14-Apr-07	11:36:39	U	42	Yes	UU
14-Apr-07	11:47:13	U	43	Yes	UU
14-Apr-07	11:55:01	U	47	Yes	UU
14-Apr-07	12:23:08	D	48	Yes	DD
14-Apr-07	12:34:56	E	32	Yes	EE
14-Apr-07	14:29:02	U	43	Yes	UU
14-Apr-07	15:22:29	D	41	Yes	DD
15-Apr-07	9:44:29	U	66	Yes	UU
15-Apr-07	9:50:54	U	75	Yes	UU

16-Apr-07	9:26:46	U	61	Yes	UU
17-Apr-07	9:32:36	U	43	Yes	UU
17-Apr-07	10:30:35	U	43	Yes	UU
17-Apr-07	10:59:42	U	39	Yes	UU
17-Apr-07	12:48:51	U	53	No	NT
17-Apr-07	17:40:08	U	38	No	NT
18-Apr-07	12:34:59	U	38	Yes	UU
18-Apr-07	14:05:11	D	44	Yes	DD
19-Apr-07	11:30:21	E	127	Yes	UE
19-Apr-07	15:57:15	U	49	Yes	UU
19-Apr-07	16:36:32	U	56	Yes	UU
19-Apr-07	16:41:13	D	53	Yes	DD
20-Apr-07	6:58:35	U	43	Yes	UU
20-Apr-07	10:03:30	D	127	No	NT
20-Apr-07	10:44:53	U	46	Yes	UU
20-Apr-07	13:14:35	E	127	Yes	DE
20-Apr-07	15:13:32	U	41	Yes	UU
21-Apr-07	13:48:16	U	51	Yes	UU
21-Apr-07	21:33:21	U	104	Yes	UU
22-Apr-07	12:25:03	U	42	Yes	UU
23-Apr-07	10:57:10	U	44	No	NT
23-Apr-07	23:14:50	E	98	Yes	UE
24-Apr-07	0:14:15	D	53	Yes	DD
24-Apr-07	12:06:47	U	51	Yes	UU
24-Apr-07	12:43:03	U	39	Yes	UU
24-Apr-07	12:49:12	U	28	Yes	UU
24-Apr-07	13:31:14	U	42	Yes	UU
24-Apr-07	13:31:23	U	40	Yes	UU
24-Apr-07	14:41:49	U	53	Yes	UU
24-Apr-07	16:54:27	U	35	Yes	UU
24-Apr-07	19:29:32	U	46	Yes	UU
24-Apr-07	23:41:15	U	38	Yes	UU
25-Apr-07	0:03:31	E	127	Yes	UE
25-Apr-07	4:34:57	E	40	Yes	DE
25-Apr-07	4:34:59	E	56	Yes	EE
25-Apr-07	4:40:42	D	81	Yes	DD
25-Apr-07	17:27:07	E	31	No	NT
26-Apr-07	10:19:48	U	37	No	NT
27-Apr-07	7:34:59	U	44	Yes	UU
27-Apr-07	7:55:53	U	35	Yes	UU
27-Apr-07	7:58:44	D	113	Yes	DD
27-Apr-07	8:27:22	U	45	Yes	UU
27-Apr-07	11:49:30	U	35	Yes	UU
27-Apr-07	11:54:42	U	46	Yes	UU
27-Apr-07	12:43:29	U	46	Yes	UU
27-Apr-07	13:26:40	D	58	Yes	DD
27-Apr-07	13:27:14	D	50	Yes	DD
27-Apr-07	13:27:15	E	39	Yes	DE
28-Apr-07	13:09:16	U	43	Yes	UU
28-Apr-07	23:51:03	U	127	Yes	UU

28-Apr-07	23:51:07	U	58	Yes	UU
29-Apr-07	0:27:33	D	127	Yes	DD
29-Apr-07	7:33:03	U	48	Yes	UU
29-Apr-07	8:08:39	U	35	Yes	UU
29-Apr-07	9:07:38	U	43	Yes	UU
29-Apr-07	10:22:26	U	39	Yes	UU
29-Apr-07	11:11:28	U	54	Yes	UU
29-Apr-07	11:11:31	U	39	Yes	UU
29-Apr-07	11:24:03	U	46	Yes	UU
29-Apr-07	11:45:37	U	43	Yes	UU
29-Apr-07	13:44:00	U	41	Yes	UU
29-Apr-07	14:55:52	D	43	Yes	DD
29-Apr-07	14:57:15	D	87	Yes	DD
30-Apr-07	11:16:39	U	45	Yes	UU
30-Apr-07	11:45:44	E	126	Yes	DE
30-Apr-07	16:17:32	U	41	Yes	UU
30-Apr-07	16:17:41	D	35	Yes	DD
01-May-07	4:16:16	U	99	Yes	UU
01-May-07	5:13:15	D	66	Yes	DD
01-May-07	10:31:06	U	41	Yes	UU
01-May-07	11:10:27	D	99	Yes	DD
02-May-07	18:40:04	E	63	No	NT
03-May-07	1:49:38	E	61	No	NT
03-May-07	3:58:33	E	49	No	NT
04-May-07	10:45:55	U	53	No	NT
04-May-07	10:51:19	U	43	No	NT
04-May-07	14:08:54	U	50	No	NT
04-May-07	14:20:51	E	112	No	NT
04-May-07	14:23:36	U	57	No	NT
05-May-07	11:08:15	U	54	No	NT
05-May-07	11:14:04	E	27	No	NT
06-May-07	4:40:21	U	53	No	NT
06-May-07	5:19:42	E	127	No	NT
06-May-07	5:27:42	D	127	No	NT
06-May-07	23:41:21	D	34	No	NT
07-May-07	8:56:00	U	38	No	NT
07-May-07	22:40:12	E	119	No	NT
07-May-07	22:40:14	E	90	No	NT
07-May-07	22:41:25	U	127	No	NT
07-May-07	23:24:54	E	104	No	NT
08-May-07	9:08:16	U	58	No	NT
08-May-07	16:09:16	U	44	No	NT
08-May-07	17:39:30	U	44	No	NT
08-May-07	20:13:32	D	127	No	NT
10-May-07	0:50:05	E	124	No	NT
10-May-07	3:15:28	D	77	No	NT
10-May-07	10:03:31	U	44	No	NT
10-May-07	19:23:26	U	46	No	NT
11-May-07	12:45:57	U	36	Yes	UU
11-May-07	14:44:38	U	42	Yes	UU

11-May-07	16:25:33	U	44	Yes	UU
11-May-07	17:17:16	U	42	Yes	UU
11-May-07	17:36:47	U	54	Yes	UU
11-May-07	18:32:05	U	48	Yes	UU
12-May-07	3:22:08	U	44	Yes	UU
12-May-07	8:18:22	U	67	Yes	UU
12-May-07	9:03:49	U	44	Yes	UU
12-May-07	9:24:04	U	38	Yes	UU
12-May-07	10:40:30	D	48	Yes	DD
12-May-07	11:18:09	U	44	Yes	UU
12-May-07	14:03:20	U	43	Yes	UU
12-May-07	14:05:44	E	127	Yes	DE
12-May-07	16:30:08	U	40	Yes	UU
13-May-07	2:08:57	E	127	Yes	UE
13-May-07	6:29:06	U	40	Yes	UU
13-May-07	7:01:17	U	40	Yes	UU

Appendix 2. Daily Mean Water Temperatures

Date	Temp˚ C
19-Jan	1.48
20-Jan	1.48
21-Jan	1.48
22-Jan	1.68
23-Jan	1.78
24-Jan	2.00
25-Jan	1.94
26-Jan	1.79
27-Jan	1.71
28-Jan	1.67
29-Jan	1.79
30-Jan	1.75
31-Jan	1.68
1-Feb	1.70
2-Feb	1.67
3-Feb	1.70
4-Feb	1.89
5-Feb	2.09
6-Feb	2.19
7-Feb	2.22
8-Feb	2.27
9-Feb	2.26
10-Feb	2.18
11-Feb	2.06
12-Feb	2.14
13-Feb	2.27
14-Feb	2.38
15-Feb	2.46
16-Feb	2.48
17-Feb	2.67
18-Feb	2.74
19-Feb	2.65
20-Feb	2.59
21-Feb	2.49
22-Feb	2.38

23-Feb	2.18
24-Feb	2.20
25-Feb	2.30
26-Feb	2.34
27-Feb	2.45
28-Feb	2.43
1-Mar	2.28
2-Mar	2.16
3-Mar	2.28
4-Mar	2.52
5-Mar	2.59
6-Mar	2.67
7-Mar	2.71
8-Mar	2.58
9-Mar	2.43
10-Mar	2.43
11-Mar	2.48
12-Mar	2.47
13-Mar	2.32
14-Mar	2.13
15-Mar	2.19
16-Mar	2.30
17-Mar	2.44
18-Mar	2.51
19-Mar	2.48
20-Mar	2.51
21-Mar	2.52
22-Mar	2.73
23-Mar	2.87
24-Mar	2.87
25-Mar	2.90
26-Mar	2.88
27-Mar	2.83
28-Mar	2.63
29-Mar	2.35
30-Mar	2.52
31-Mar	2.67
1-Apr	2.71
2-Apr	2.80
3-Apr	2.82
4-Apr	2.97
5-Apr	3.08
6-Apr	3.18

7-Apr	3.30
8-Apr	3.43
9-Apr	3.53
10-Apr	3.55
11-Apr	3.53
12-Apr	3.62
13-Apr	3.69
14-Apr	3.68
15-Apr	3.69
16-Apr	3.73
17-Apr	3.94
18-Apr	4.25
19-Apr	4.55
20-Apr	4.72
21-Apr	5.17
22-Apr	5.63
23-Apr	5.87
24-Apr	6.06
25-Apr	6.18
26-Apr	6.35
27-Apr	6.45
28-Apr	6.35
29-Apr	6.36
30-Apr	6.45
1-May	6.89
2-May	7.03
3-May	7.16
4-May	7.34
5-May	7.57
6-May	7.25
7-May	7.07
8-May	7.05
9-May	7.14
10-May	7.40
11-May	7.82
12-May	8.14
13-May	8.28