Results of the Kloiya River Resistivity Counter 2006

Skeena Fisheries Report Series SK 153

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Executive Summary

A Logie 2100C resistivity counter was installed at the Kloiya River on November 30, 2005. 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. 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. 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 2.37° C on December 18, and the highest mean daily water temperature was 11.55° C on May 23. The counter was removed on May 26, 2006.

The first event was recorded on February 12, 2006. There was very limited steelhead migration through the fishway until the first week in April. Increased activity appeared to coincide with water temperatures approaching 5° C and increased flows in the fishway. The majority (95%) of the upstream migrants were recorded between April 4 and May 26. The highest daily upstream count was 17 on April 24.Trace data was recorded for 26% of the events recorded by counter. Trace data indicated that the counter efficiency for upstream migrants was 81% and 58% for downstream migrants. The 2006 steelhead escapement, upstream of the Kloiya River dam is estimated to be 146.

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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 a approximate length of two km. A dam with a vertical height of approximately 7 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 River steelhead population is limited to a study undertaken in 1981 by Ministry of Environment commissioned by the Salmonid Enhancement Program. This studies objective was to quantify juvenile steelhead abundance and estimate 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.

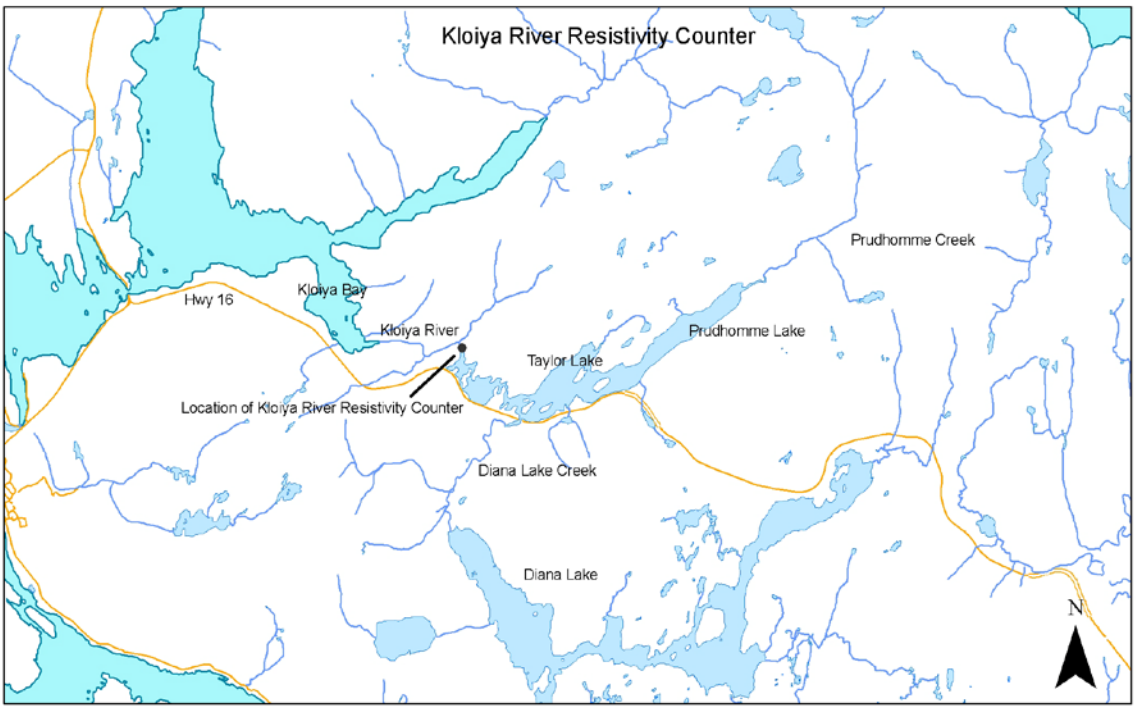

Figure 1. Location of Kloiya River resistivity counter.

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

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 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 productivity occurs in tributaries above the fishway (*Beere pers. comm*).

In 2006, trace data, produced by the Logie 2100 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 temperature (°C) hourly. One data logger recorded ambient air temperature, and the other two were located in the fishway and Taylor Lake respectively.

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 dependant 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 10mg/l respectively. As a result, the counter gain was set at a value of 250 to compensate for the low conductivity. Threshold values required for fish identification was set at 20. Counter software used during the 2006 project was version 9.10.

4.0 Results

4.1 Counter Efficiency

The Kloiya River resistivity counter was installed and operational on November 30, 2005. The first fish was recorded on March 1, 2006 and the last line of data was recorded on May 26, 2006. During this time period, the counter recorded 246 up counts, 88 down counts and 121 events. Events indicate a change in conductivity that was not recognized by the counter algorithm as a fish. A total of 455 rows of data were recorded as upstream counts, downstream counts and events (Table 1).

Date	Time	Direction	P.S.S
07-Apr	11:13:27	E	54
07-Apr	11:55:10	U	28
07-Apr	13:32:45	U	38
07-Apr	18:16:21	U	34
07-Apr	18:32:27	D	32
09-Apr	9:08:35	U	44
09-Apr	12:50:26	E	24
10-Apr	12:01:34	U	45
10-Apr	12:59:10	U	28
10-Apr	12:59:57	U	27
10-Apr	13:47:41	U	29
10-Apr	17:32:45	U	30
10-Apr	19:44:43	E	127

Table 1. Example of text data collected from counter in 2006**.**

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 algorithm's classification. In 2006, 116 or 26% of the counter records had corresponding trace data that can be used for analysis. These data were collected between March 13 and April 16, 2006. 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 (54) by the total number of up counts UU+UE (67). This results in a upstream efficiency estimate of 81%. Counter efficiency for downstream migrants was calculated by dividing the correctly classified number of down counts DD (25) by the total number of down counts DD+ DE (43). Therefore, the counter efficiency for downstream migrants was calculated to be 58%. The remaining seven 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. Figure 2 and 3 shows examples of downstream and upstream migrants incorrectly classified as an event.

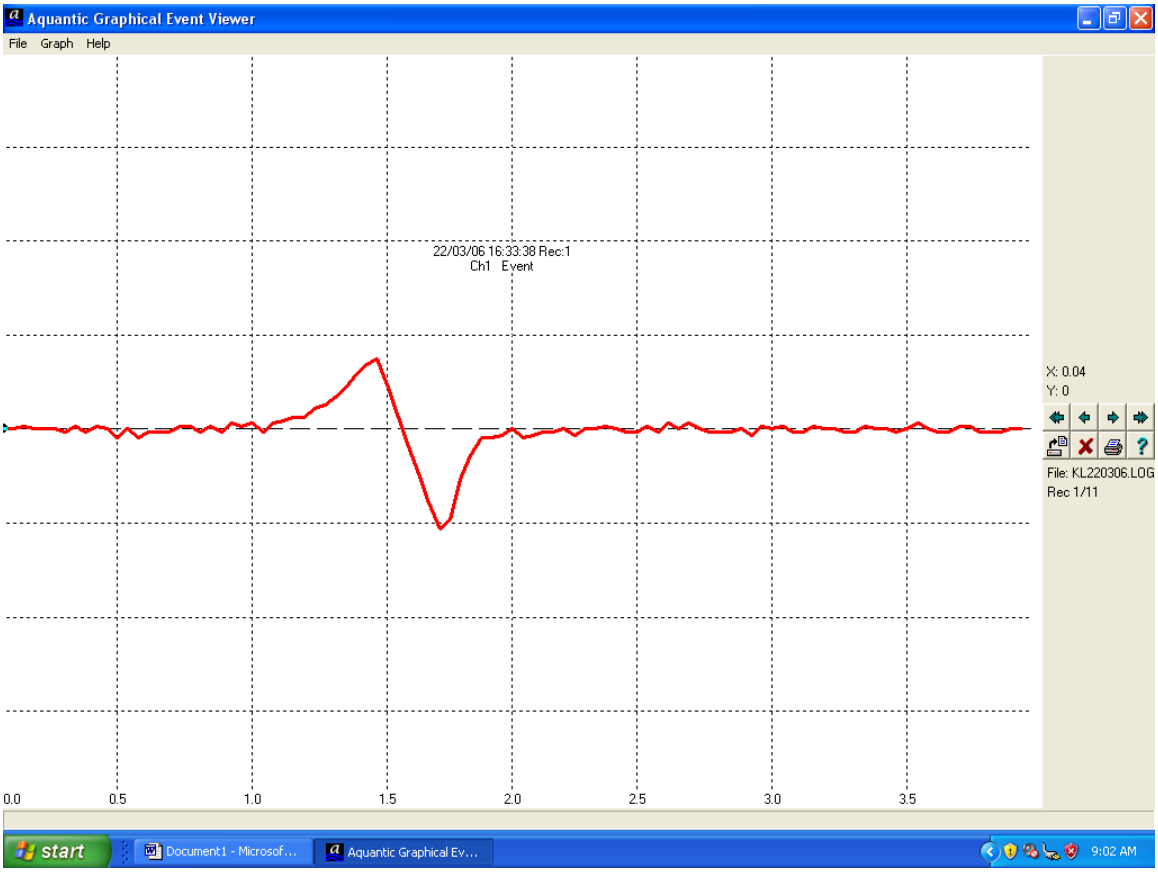

Figure 2. Downstream migrant incorrectly classified as a non fish event.

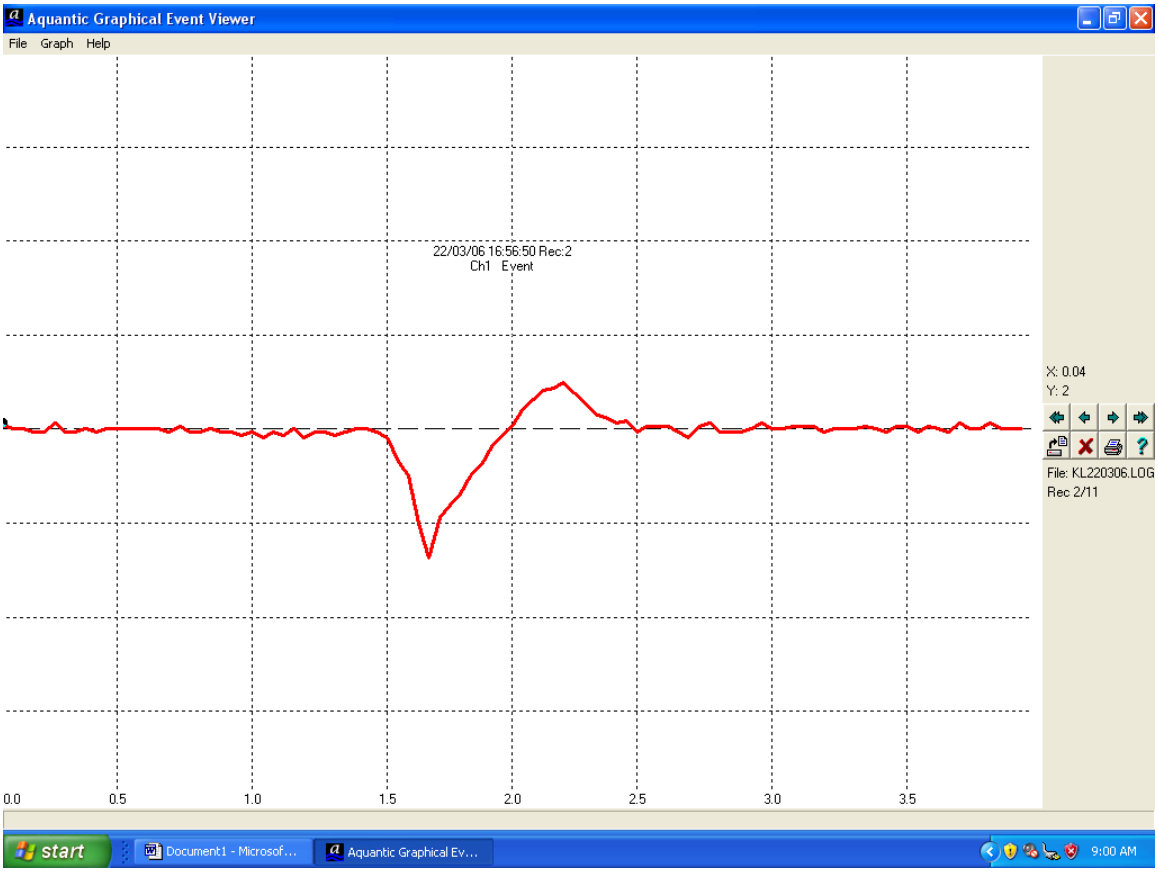

Figure 3. Upstream migrant incorrectly classified as a non fish event.

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.

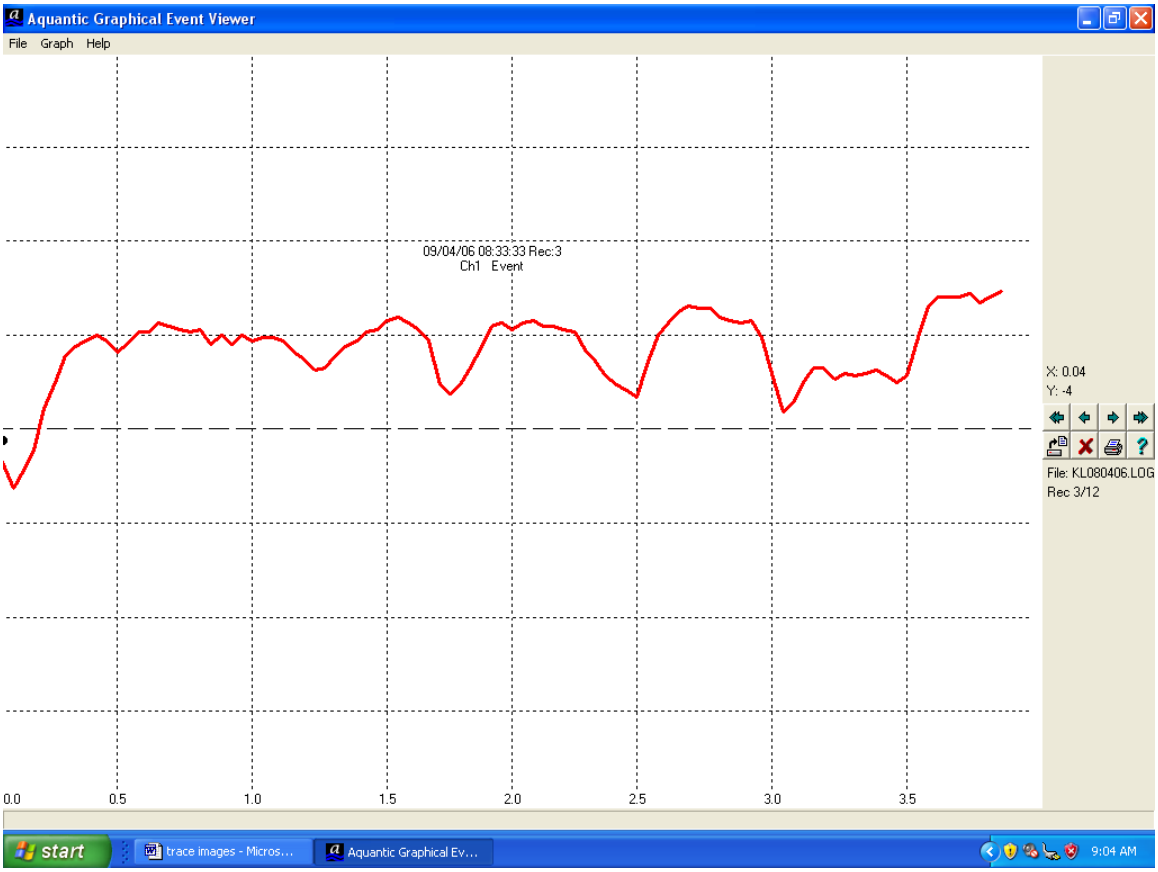

Figure 4. Change in conductivity correctly classified as a non fish event.

4.2 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 34% of the events logged by the counter were upstream migrants. In comparison, 47% of the events were downstream migrants. These values are applied to the remaining events where trace data does not exist. There are 83 logged events where trace data does not exist. To estimate up counts 83 is multiplied by 0.34. Therefore, it is estimated that 28 upstream migrants, where trace data does not exist, were not correctly classified. The estimate for downstream migrants is 83 multiplied by 0.47. It is estimated that 39 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
(261+28)- (104+39) = 146

4.3 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 November 30, 2005. 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 1. 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 November 30, 2005 to April 30, 2006 there were no counts recorded until March 1, 2006. Between March 1 and April 3, 5% of the recorded steelhead 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 seventeen. The peak daily upstream count occurred on April 24 (Fig 5).

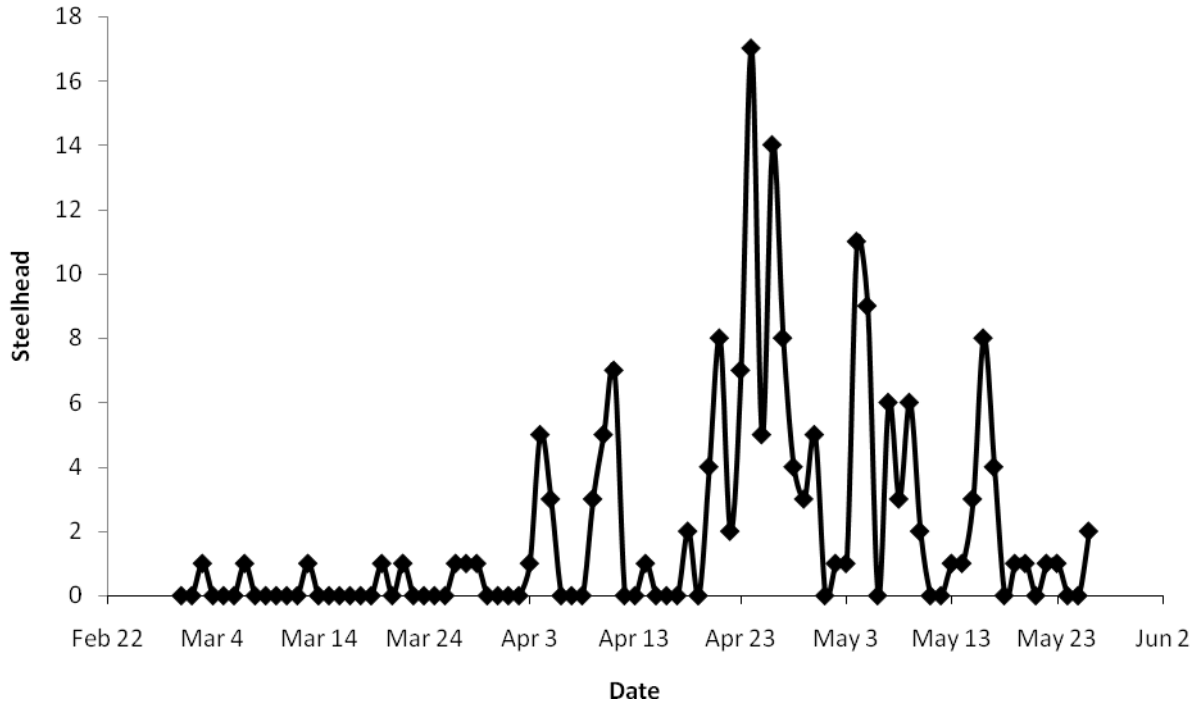

Figure 5. Uncorrected net daily up counts March 1 to May 26.

4.4 Environmental Parameters

Hourly water temperatures were recorded by Optic Stowaway temperature data loggers. Water temperatures were recorded between December 1, 2005 and May 26, 2006. Water temperature ranged between 2.34˚C (Dec 18) and 11.55˚C (May 23). Mean water temperature for the duration of the 2006 project was 4.56˚C (SD=2.26).

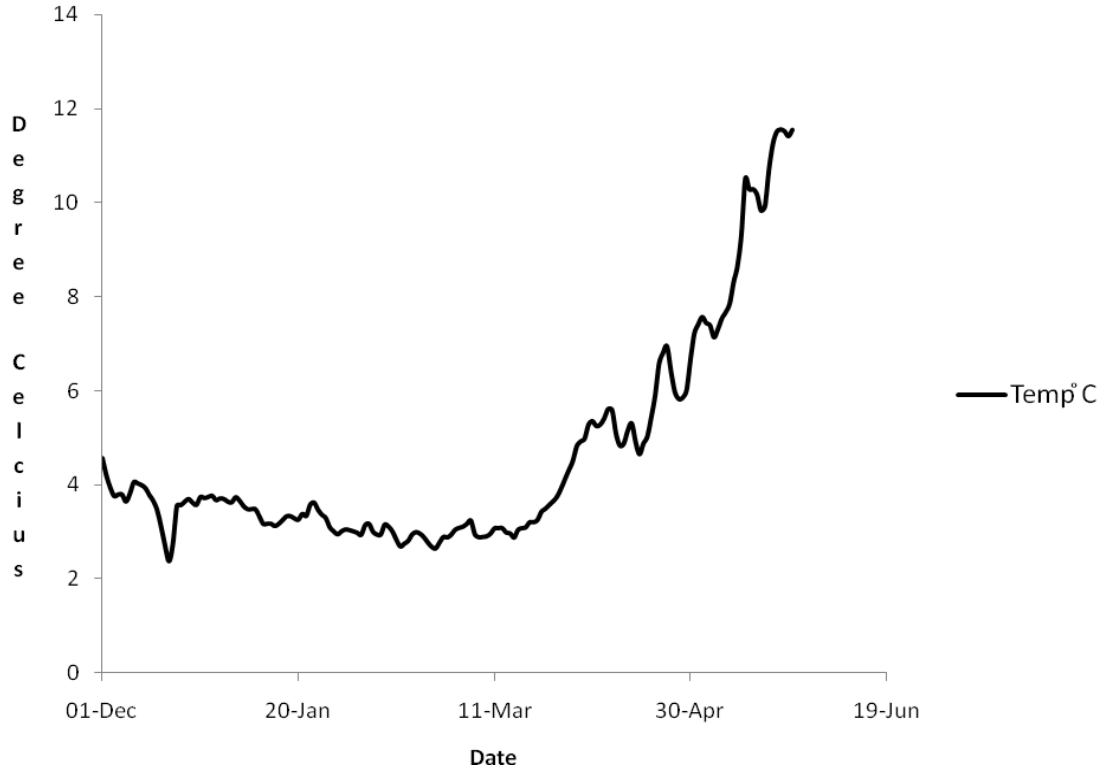

Figure 6. Mean daily water temperatures Kloiya River 2006.

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 7 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.

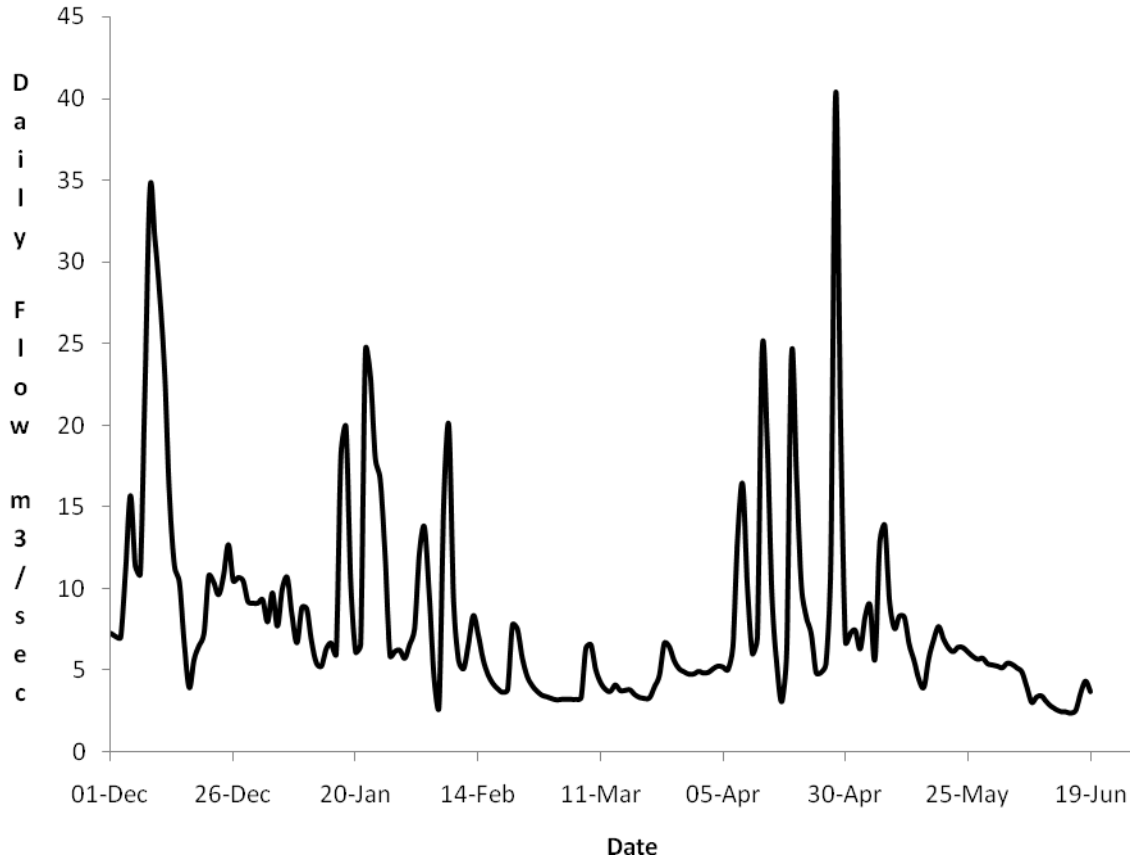

Figure 7. Mean daily flow (m^3/sec) in the Kloiya River December to June 2006 (Env Canada survey station Kloiya River).

4.5 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 2006, no migration was recorded until March 1. At this time, up counts were generally followed by down counts. This indicated that steelhead were not entering the lake on their initial migration through the fishway. This behaviour remained consistent until the first week in April when the counter data suggested that steelhead passing through the counter were migrating into the lake and on to their respective spawning tributaries. This behavioural change coincided with increasing water temperatures and flow (Fig 6) (Fig 7). Further analysis indicated that water temperature exceeding 5˚C coincided with increased activity in the fishway. During the project, 87% of all net up counts were recorded when water temperatures were greater than 5˚C (Table 3). The number of project days when daily water temperature fit this criteria is equal to 48 days. Water temperature was collected for 177 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	%
0.00-0.99	0	0.00
1.00-1.99	0	0.00
2.00-2.99	3	1.15
3.00-3.99	10	3.83
4.00-4.99	22	8.43
5.00-5.99	85	32.57
6.00-6.99	52	19.92
7.00-7.99	55	21.07
8.00-8.99	0	0.00
9.00-9.99	11	4.21
Greater than 10	23	8.81
Total	261	100

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

4.0 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 by small turbine 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 the Bonaparte River fishway.

Counter data collected in 2006 shows that steelhead do not migrate through the fishway until mid to late spring. Steelhead angling opportunities on the Kloiya River begin in late November indicating that steelhead that migrate into the Kloiya River in early , middle and late winter remain in the short section of river below the dam where most of the angling activity occurs. This is contrary to the assumption that steelhead that migrated into the Kloiya River past through the lower river in a short period of time thereby reducing their exposure to harvest or multiple recaptures. The 2006 data also indicated that many steelhead do not simply ascend the fishway and enter the Taylor Lake on their initial attempt. Multiple up and down migrations were recorded in the fishway over the duration of the project. Investigations into facilitating fish passage through the fishway could be one of the benefits of the 2006 project.

The 2006 project provided an opportunity to evaluate the practicality of continuing this project as a long term index for winter-run steelhead on the North Coast. The conclusion is that the goals and objectives of this project were achieved and presents a viable opportunity to enumerate winter-run steelhead on a annual basis and should be continued.

4.0 Recommendations

- Incorporate digital video into the project to confirm that that only species utilizing the fishway during the project are steelhead.
- Investigate other options to generate electrical power for counter operation.
- Investigate options for facilitating fish migration through the fishway.
- Increase counter gain settings in future years to compensate for low conductivity and improve counter efficiency.

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Appendix 1. Counter data

Date	Time	Conductivity	Channel	PSS	Event Description
12-Feb	14:35:48	84	1	29	E
23-Feb	0:58:37	84	1	113	E
01-Mar	13:53:13	84	1	27	D
01-Mar	23:48:20	84	1	37	U
02-Mar	1:56:15	84	1	32	D
03-Mar	17:37:58	84	1	28	U
06-Mar	12:07:35	84	1	28	E
07-Mar	1:27:57	84	1	127	U
07-Mar	8:00:22	84	1	111	E
08-Mar	16:47:36	84	1	28	D
08-Mar	17:02:07	84	1	35	E
09-Mar	20:58:13	84	1	29	E
09-Mar	22:31:04	84	1	27	D
12-Mar	1:37:01	84	1	92	E
13-Mar	17:42:18	84	1	27	UU
14-Mar	21:34:23	84	1	27	UU
14-Mar	13:56:37	84	1	35	DD
14-Mar	23:14:44	84	1	31	DD
19-Mar	12:12:21	84	1	28	UU
19-Mar	13:38:44	84	1	102	DE
19-Mar	14:21:54	84	1	28	DD
20-Mar	22:33:12	84	1	127	U
21-Mar	0:40:12	84	1	6	E
22-Mar	16:33:38	84	1	34	UE
22-Mar	21:56:55	84	1	74	UE
22-Mar	16:56:50	84	1	44	DE
23-Mar	3:30:24	84	1	28	UU
23-Mar	0:39:28	84	1	127	DE
24-Mar	1:15:41	84	1	87	UU
24-Mar	6:52:09	84	1	69	DD
26-Mar	15:19:40	84	1	32	UU
26-Mar	16:13:47	84	1	127	EE
26-Mar	16:13:51	84	1	42	DD
27-Mar	5:13:00	84	1	98	UE
28-Mar	16:17:36	84	1	33	UU
28-Mar	19:31:23	84	1	127	UE
28-Mar	20:59:11	84	1	28	UE
28-Mar	23:44:39	84	1	88	DE
28-Mar	23:01:06	84	1	72	DD
29-Mar	14:54:52	84	1	30	UU
29-Mar	15:29:04	84	1	27	UU
29-Mar	17:24:35	84	1	31	UE
29-Mar	17:37:50	84	1	28	DD
29-Mar	18:09:51	84	1	48	DD
31-Mar	14:38:29	84	1	29	UU
31-Mar	13:27:38	84	1	26	UE

31-Mar	15:42:03	84	1	116	DE
31-Mar	15:39:21	84	1	41	DD
01-Apr	18:08:05	84	1	29	DD
02-Apr	18:34:07	84	1	32	UU
02-Apr	19:34:21	84	1	96	DE
02-Apr	20:12:09	84	1	122	DE
03-Apr	14:17:54	84	1	27	UU
04-Apr	4:29:26	84	1	49	UU
04-Apr	8:47:25	84	1	30	UU
04-Apr	9:35:39	84	1	35	UU
04-Apr	14:44:40	84	1	26	UU
04-Apr	15:06:45	84	1	27	UU
04-Apr	15:39:36	84	1	26	UU
04-Apr	16:13:08	84	1	30	UU
04-Apr	17:12:32	84	1	32	UU
04-Apr	17:16:53	84	1	31	UU
04-Apr	17:42:09	84	1	46	UE
04-Apr	14:39:46	84	1	106	DE
04-Apr	17:10:11	84	1	64	DD
04-Apr	17:36:24	84	1	29	DD
04-Apr	17:50:17	84	1	32	DD
04-Apr	17:55:06	84	1	55	DD
05-Apr	3:28:02	84	1	74	UU
05-Apr	13:08:38	84	1	26	UU
05-Apr	4:08:36	84	1	118	DE
05-Apr	14:11:03	84	1	32	E
05-Apr	17:01:48	84	1	26	E
05-Apr	17:17:01	84	1	31	U
05-Apr	18:45:31	84	1	34	U
05-Apr	20:43:34	84	1	29	E
07-Apr	11:55:10	84	1	28	UU
07-Apr	13:32:45	84	1	38	UU
07-Apr	18:16:21	84	1	34	UU
07-Apr	11:13:27	84	1	54	DE
07-Apr	14:27:19	84	1	127	DE
07-Apr	18:32:27	84	1	32	DD
09-Apr	9:08:35	84	1	44	UU
09-Apr	8:33:25	84	1	121	UE
09-Apr	12:50:26	84	1	24	UE
09-Apr	8:33:30	84	1	107	EE
09-Apr	8:33:33	84	1	54	EE
09-Apr	8:33:37	84	1	111	EE
10-Apr	12:01:34	84	1	45	UU
10-Apr	12:59:10	84	1	28	UU
10-Apr	12:59:57	84	1	27	UU
10-Apr	13:47:41	84	1	29	UU
10-Apr	17:32:45	84	1	30	UU
10-Apr	22:40:09	84	1	40	UU
10-Apr	23:01:28	84	1	44	UU
10-Apr	19:44:43	84	1	127	UE

10-Apr	14:05:30	84	1	97	DE
10-Apr	23:06:13	84	1	125	DD
10-Apr	23:09:50	84	1	40	DD
11-Apr	9:34:46	84	1	26	UU
11-Apr	10:54:43	84	1	30	UU
11-Apr	12:37:05	84	1	42	UU
11-Apr	13:33:07	84	1	28	UU
11-Apr	13:51:59	84	1	38	UU
11-Apr	15:52:37	84	1	29	UU
11-Apr	17:15:01	84	1	33	UU
11-Apr	17:19:32	84	1	33	UU
11-Apr	12:27:03	84	1	43	DD
12-Apr	13:46:40	84	1	31	UU
12-Apr	15:34:26	84	1	34	UU
12-Apr	16:44:56	84	1	31	UU
12-Apr	19:47:00	84	1	90	DE
12-Apr	3:15:03	84	1	28	DD
12-Apr	7:09:57	84	1	34	DD
13-Apr	11:49:10	84	1	37	UU
13-Apr	13:04:34	84	1	38	UU
13-Apr	11:49:13	84	1	127	EE
13-Apr	1:43:29	84	1	40	DE
13-Apr	9:22:30	84	1	122	DE
13-Apr	13:04:40	84	1	35	DD
14-Apr	16:02:47	84	1	32	UU
15-Apr	14:18:18	84	1	29	UU
15-Apr	16:50:58	84	1	30	DD
16-Apr	17:18:24	84	1	28	UU
16-Apr	17:26:35	84	1	86	DD
18-Apr	11:30:55	84	1	30	UU
18-Apr	14:37:41	84	1	32	UU
18-Apr	16:06:55	84	1	35	UU
18-Apr	13:53:20	84	1	26	UE
18-Apr	17:04:46	84	1	55	EE
18-Apr	17:03:10	84	1	127	DE
18-Apr	16:49:30	84	1	41	DD
19-Apr	7:33:25	84	1	55	UU
19-Apr	7:33:46	84	1	84	UE
19-Apr	7:33:28	84	1	66	EE
19-Apr	7:33:27	84	1	125	DE
19-Apr	7:33:30	84	1	68	DE
19-Apr	4:36:05	84	1	30	DD
19-Apr	15:58:42	84	1	71	D
19-Apr	16:29:20	84	1	127	D
19-Apr	16:50:24	84	1	38	D
19-Apr	16:51:52	84	1	118	E
19-Apr	16:51:54	84	1	97	E
19-Apr	17:10:09	84	1	48	U
19-Apr	17:10:17	84	1	63	E
19-Apr	17:10:21	84	1	91	D

19-Apr	17:25:22	84	1	75	E
19-Apr	17:25:28	84	1	97	D
19-Apr	17:38:31	84	1	43	U
19-Apr	18:53:43	84	1	42	D
20-Apr	9:06:29	84	1	28	E
20-Apr	13:44:55	84	1	31	U
20-Apr	13:48:07	84	1	32	U
20-Apr	15:51:58	84	1	31	U
20-Apr	17:32:36	84	1	35	U
21-Apr	12:27:04	84	1	26	U
21-Apr	12:44:50	84	1	27	U
21-Apr	12:53:28	84	1	30	U
21-Apr	13:37:59	84	1	32	U
21-Apr	13:47:06	84	1	28	U
21-Apr	14:29:08	84	1	34	U
21-Apr	14:36:00	84	1	31	U
21-Apr	14:41:44	84	1	61	D
21-Apr	14:44:23	84	1	42	U
21-Apr	14:45:54	84	1	67	E
21-Apr	14:55:52	84	1	36	U
21-Apr	23:42:44	84	1	86	E
22-Apr	4:15:35	84	1	26	E
22-Apr	4:28:47	84	1	77	E
22-Apr	10:34:36	84	1	27	E
22-Apr	11:34:17	84	1	26	U
22-Apr	13:00:38	84	1	41	D
22-Apr	13:38:32	84	1	26	E
22-Apr	14:13:23	84	1	27	E
22-Apr	15:45:36	84	1	28	U
22-Apr	16:13:51	84	1	28	U
23-Apr	9:36:30	84	1	27	U
23-Apr	9:58:09	84	1	28	E
23-Apr	11:38:39	84	1	30	U
23-Apr	12:16:46	84	1	28	U
23-Apr	12:24:38	84	1	125	E
23-Apr	13:15:38	84	1	33	U
23-Apr	17:26:28	84	1	32	U
23-Apr	18:06:13	84	1	30	U
23-Apr	23:30:42	84	1	35	U
24-Apr	0:08:43	84	1	127	U
24-Apr	0:25:36	84	1	38	D
24-Apr	0:46:49	84	1	82	E
24-Apr	1:00:30	84	1	35	U
24-Apr	1:16:21	84	1	38	D
24-Apr	1:33:56	84	1	91	E
24-Apr	1:43:26	84	1	35	D
24-Apr	3:36:55	84	1	35	D
24-Apr	5:27:58	84	1	29	U
24-Apr	6:15:48	84	1	103	E
24-Apr	6:15:50	84	1	30	E

24-Apr	6:18:42	84	1	27	U
24-Apr	6:19:53	84	1	57	D
24-Apr	8:54:19	84	1	37	D
24-Apr	9:36:29	84	1	31	U
24-Apr	9:37:19	84	1	32	E
24-Apr	10:10:17	84	1	39	D
24-Apr	10:21:24	84	1	33	U
24-Apr	11:54:18	84	1	127	E
24-Apr	14:34:21	84	1	36	U
24-Apr	15:18:16	84	1	30	U
24-Apr	15:24:04	84	1	26	U
24-Apr	15:56:06	84	1	30	U
24-Apr	15:57:40	84	1	31	U
24-Apr	15:58:02	84	1	31	U
24-Apr	16:00:14	84	1	30	U
24-Apr	16:00:40	84	1	33	U
24-Apr	16:33:43	84	1	33	U
24-Apr	16:44:06	84	1	33	U
24-Apr	17:00:34	84	1	33	U
24-Apr	17:29:49	84	1	38	U
24-Apr	17:32:20	84	1	28	U
24-Apr	17:48:08	84	1	47	D
24-Apr	18:05:36	84	1	26	U
24-Apr	18:52:42	84	1	28	D
24-Apr	19:30:52	84	1	31	U
24-Apr	20:22:33	84	1	100	E
24-Apr	21:04:11	84	1	127	U
24-Apr	21:08:04	84	1	39	U
24-Apr	21:08:49	84	1	36	U
24-Apr	23:28:09	84	1	69	U
24-Apr	23:31:47	84	1	52	U
25-Apr	0:27:59	84	1	49	U
25-Apr	0:29:00	84	1	34	D
25-Apr	1:27:08	84	1	81	U
25-Apr	1:45:57	84	1	44	D
25-Apr	2:22:37	84	1	115	D
25-Apr	3:46:15	84	1	73	E
25-Apr	3:47:10	84	1	82	D
25-Apr	4:09:21	84	1	59	D
25-Apr	8:15:31	84	1	26	U
25-Apr	11:02:56	84	1	36	E
25-Apr	11:24:43	84	1	32	U
25-Apr	11:28:32	84	1	30	U
25-Apr	12:43:08	84	1	28	U
25-Apr	13:11:38	84	1	39	E
25-Apr	13:11:40	84	1	34	E
25-Apr	13:33:11	84	1	56	D
25-Apr	13:44:31	84	1	29	U
25-Apr	13:46:23	84	1	27	U
25-Apr	13:59:24	84	1	43	U

25-Apr	14:56:17	84	1	28	U
25-Apr	15:22:46	84	1	29	U
26-Apr	5:27:58	84	1	36	U
26-Apr	9:42:04	84	1	35	U
26-Apr	9:46:22	84	1	45	D
26-Apr	11:05:59	84	1	42	D
26-Apr	12:06:38	84	1	33	U
26-Apr	13:07:04	84	1	33	U
26-Apr	13:12:54	84	1	34	U
26-Apr	13:18:52	84	1	31	U
26-Apr	13:21:53	84	1	26	U
26-Apr	13:43:22	84	1	33	E
26-Apr	13:51:17	84	1	28	U
26-Apr	13:56:24	84	1	127	E
26-Apr	14:11:32	84	1	31	U
26-Apr	14:31:50	84	1	32	U
26-Apr	15:08:59	84	1	31	U
26-Apr	15:40:02	84	1	35	D
26-Apr	16:25:10	84	1	44	U
26-Apr	16:34:58	84	1	46	D
26-Apr	17:09:14	84	1	29	U
26-Apr	17:20:54	84	1	40	U
26-Apr	17:42:46	84	1	31	U
26-Apr	18:05:41	84	1	127	E
26-Apr	21:57:57	84	1	32	U
26-Apr	21:58:24	84	1	53	U
26-Apr	22:05:03	84	1	27	U
27-Apr	0:05:01	84	1	68	D
27-Apr	1:38:34	84	1	35	E
27-Apr	14:53:57	84	1	31	U
27-Apr	14:58:31	84	1	33	U
27-Apr	15:40:49	84	1	36	U
27-Apr	16:52:05	84	1	33	U
27-Apr	17:18:01	84	1	31	E
27-Apr	17:48:56	84	1	44	D
27-Apr	17:49:58	84	1	55	U
27-Apr	17:57:01	84	1	44	D
27-Apr	18:45:17	84	1	32	U
27-Apr	18:46:14	84	1	39	U
27-Apr	18:46:27	84	1	35	U
27-Apr	19:21:39	84	1	33	U
27-Apr	19:23:40	84	1	36	U
27-Apr	19:36:20	84	1	127	E
27-Apr	19:49:33	84	1	45	U
27-Apr	19:55:02	84	1	87	U
27-Apr	20:09:30	84	1	127	E
27-Apr	20:18:34	84	1	63	D
28-Apr	12:34:58	84	1	127	U
28-Apr	18:47:00	84	1	31	U
28-Apr	18:47:04	84	1	55	E

28-Apr	18:47:16	84	1	77	E
28-Apr	18:47:19	84	1	116	E
28-Apr	19:51:44	84	1	89	U
28-Apr	20:12:23	84	1	127	U
29-Apr	10:54:22	84	1	33	U
29-Apr	12:17:07	84	1	30	U
29-Apr	19:03:24	84	1	31	U
30-Apr	10:20:13	84	1	28	E
30-Apr	11:17:19	84	1	27	E
30-Apr	11:23:42	84	1	35	U
30-Apr	12:43:58	84	1	28	U
30-Apr	12:59:11	84	1	30	U
30-Apr	13:27:18	84	1	30	U
30-Apr	13:37:22	84	1	26	U
30-Apr	14:53:41	84	1	29	E
30-Apr	15:07:59	84	1	46	D
30-Apr	15:08:03	84	1	30	E
30-Apr	15:09:42	84	1	122	E
30-Apr	15:10:55	84	1	29	U
01-May	5:28:08	84	1	127	U
01-May	10:59:08	84	1	29	U
01-May	11:13:32	84	1	34	D
01-May	14:42:18	84	1	36	D
01-May	22:43:19	84	1	30	D
02-May	0:15:12	84	1	29	D
02-May	12:30:45	84	1	31	U
02-May	12:33:57	84	1	38	D
02-May	14:53:19	84	1	34	U
02-May	15:18:04	84	1	39	D
02-May	17:18:18	84	1	29	U
02-May	17:29:45	84	1	37	U
03-May	8:04:51	84	1	127	E
03-May	14:11:55	84	1	60	D
03-May	15:37:23	84	1	33	U
03-May	21:01:22	84	1	46	U
04-May	5:15:54	84	1	40	U
04-May	10:55:41	84	1	35	U
04-May	10:56:31	84	1	27	U
04-May	11:01:08	84	1	38	U
04-May	11:49:35	84	1	28	E
04-May	13:05:52	84	1	33	U
04-May	13:19:49	84	1	127	E
04-May	14:08:05	84	1	32	U
04-May	14:12:12	84	1	28	U
04-May	14:21:39	84	1	51	D
04-May	14:42:50	84	1	30	U
04-May	15:25:53	84	1	32	U
04-May	16:51:07	84	1	28	U
04-May	17:11:26	84	1	31	U
04-May	19:35:02	84	1	45	U

04-May	19:51:12	84	1	41	U
04-May	20:09:37	84	1	76	E
04-May	21:24:25	84	1	34	D
05-May	6:42:17	84	1	33	U
05-May	6:43:40	84	1	127	E
05-May	7:20:46	84	1	44	U
05-May	7:20:53	84	1	32	U
05-May	7:26:16	84	1	41	D
05-May	8:17:57	84	1	31	U
05-May	8:46:03	84	1	33	U
05-May	10:33:00	84	1	30	U
05-May	16:59:06	84	1	26	U
05-May	17:21:58	84	1	41	U
05-May	19:10:08	84	1	31	U
05-May	19:31:50	84	1	30	U
05-May	19:34:37	84	1	127	E
05-May	19:35:22	84	1	90	E
05-May	22:20:05	84	1	100	E
06-May	0:45:55	84	1	127	E
07-May	10:50:54	84	1	27	U
07-May	13:35:03	84	1	26	E
07-May	14:13:43	84	1	28	U
07-May	14:17:51	84	1	27	E
07-May	14:38:10	84	1	29	U
07-May	15:32:36	84	1	36	U
07-May	16:04:07	84	1	32	U
07-May	16:56:26	84	1	31	U
07-May	18:28:39	84	1	28	E
08-May	9:58:13	84	1	33	U
08-May	13:59:07	84	1	35	U
08-May	16:12:28	84	1	35	U
09-May	2:07:22	84	1	110	E
09-May	8:52:23	84	1	27	U
09-May	10:26:05	84	1	29	U
09-May	16:14:01	84	1	30	U
09-May	16:27:37	84	1	30	U
09-May	16:39:09	84	1	127	E
09-May	16:55:37	84	1	27	E
09-May	16:55:39	84	1	31	U
09-May	17:02:25	84	1	127	E
09-May	17:33:11	84	1	29	U
09-May	18:21:34	84	1	127	E
09-May	18:22:51	84	1	32	U
09-May	18:40:49	84	1	37	D
09-May	18:45:42	84	1	35	D
09-May	19:05:48	84	1	36	U
09-May	19:19:23	84	1	43	D
09-May	19:42:36	84	1	43	U
10-May	18:22:47	84	1	31	U
10-May	18:54:55	84	1	29	U

10-May	19:12:04	84	1	127	E
10-May	19:29:16	84	1	31	U
10-May	19:49:21	84	1	79	D
10-May	19:51:30	84	1	30	U
10-May	20:14:39	84	1	49	D
13-May	1:23:54	84	1	127	E
13-May	12:18:00	84	1	28	U
14-May	14:04:31	84	1	35	U
14-May	18:14:28	84	1	37	D
14-May	19:16:38	84	1	34	U
14-May	19:16:39	84	1	29	U
14-May	19:30:03	84	1	44	D
14-May	19:31:04	84	1	89	E
15-May	8:50:50	84	1	30	U
15-May	12:18:29	84	1	32	U
15-May	12:40:13	84	1	26	U
15-May	12:43:11	84	1	34	U
15-May	13:20:06	84	1	29	E
15-May	14:49:48	84	1	32	D
15-May	15:36:51	84	1	101	D
15-May	15:42:43	84	1	35	U
16-May	2:30:52	84	1	57	U
16-May	2:33:42	84	1	102	E
16-May	2:48:45	84	1	41	U
16-May	3:28:54	84	1	36	D
16-May	3:37:41	84	1	61	D
16-May	6:54:31	84	1	31	U
16-May	9:08:35	84	1	29	U
16-May	12:09:41	84	1	27	U
16-May	13:08:51	84	1	127	E
16-May	14:10:02	84	1	29	U
16-May	14:11:44	84	1	45	U
16-May	14:17:19	84	1	93	E
16-May	14:28:13	84	1	33	U
16-May	14:28:27	84	1	29	E
16-May	16:30:53	84	1	34	U
16-May	17:10:13	84	1	74	E
16-May	23:24:12	84	1	49	U
16-May	23:30:17	84	1	105	E
17-May	0:01:29	84	1	28	E
17-May	0:01:31	84	1	127	E
17-May	11:47:09	84	1	32	U
17-May	11:50:52	84	1	35	D
17-May	12:36:57	84	1	32	U
17-May	14:42:31	84	1	27	U
17-May	15:44:23	84	1	31	U
17-May	19:59:28	84	1	42	U
18-May	3:54:55	84	1	125	E
18-May	4:45:58	84	1	93	D
18-May	8:08:32	84	1	36	U

18-May	14:38:49	84	1	44	D
18-May	14:54:04	84	1	67	U
18-May	15:07:39	84	1	33	D
19-May	10:31:29	84	1	39	U
20-May	16:07:22	84	1	27	U
21-May	15:11:29	84	1	27	E
22-May	13:34:55	84	1	29	U
23-May	4:05:06	84	1	65	U
26-May	17:19:39	84	1	36	U
26-May	18:43:07	84	1	26	E
26-May	21:24:06	84	1	41	U

Appendix 2. Daily mean water temperatures

Date	Temp˚ C
01-Dec	4.57
02-Dec	4.20
03-Dec	3.94
04-Dec	3.76
05-Dec	3.79
06-Dec	3.79
07-Dec	3.64
08-Dec	3.80
09-Dec	4.05
10-Dec	4.03
11-Dec	3.99
12-Dec	3.92
13-Dec	3.78
14-Dec	3.65
15-Dec	3.45
16-Dec	3.10
17-Dec	2.70
18-Dec	2.37
19-Dec	2.76
20-Dec	3.55
21-Dec	3.57
22-Dec	3.64
23-Dec	3.70
24-Dec	3.62
25-Dec	3.57
26-Dec	3.74
27-Dec	3.72
28-Dec	3.74
29-Dec	3.77
30-Dec	3.67
31-Dec	3.71
01-Jan	3.70
02-Jan	3.64
03-Jan	3.63
04-Jan	3.73
05-Jan	3.66
06-Jan	3.55
07-Jan	3.48
08-Jan	3.48

09-Jan	3.48
10-Jan	3.33
11-Jan	3.17
12-Jan	3.17
13-Jan	3.17
14-Jan	3.12
15-Jan	3.17
16-Jan	3.25
17-Jan	3.33
18-Jan	3.33
19-Jan	3.28
20-Jan	3.26
21-Jan	3.38
22-Jan	3.34
23-Jan	3.57
24-Jan	3.62
25-Jan	3.47
26-Jan	3.36
27-Jan	3.29
28-Jan	3.10
29-Jan	3.01
30-Jan	2.95
31-Jan	3.01
01-Feb	3.05
02-Feb	3.04
03-Feb	3.01
04-Feb	2.98
05-Feb	2.94
06-Feb	3.14
07-Feb	3.17
08-Feb	3.00
09-Feb	2.94
10-Feb	2.94
11-Feb	3.15
12-Feb	3.11
13-Feb	3.00
14-Feb	2.83
15-Feb	2.69
16-Feb	2.75
17-Feb	2.81
18-Feb	2.94
19-Feb	2.99
20-Feb	2.96

21-Feb	2.89
22-Feb	2.77
23-Feb	2.68
24-Feb	2.65
25-Feb	2.77
26-Feb	2.89
27-Feb	2.88
28-Feb	2.94
01-Mar	3.04
02-Mar	3.08
03-Mar	3.11
04-Mar	3.17
05-Mar	3.24
06-Mar	2.95
07-Mar	2.88
08-Mar	2.89
09-Mar	2.90
10-Mar	2.96
11-Mar	3.07
12-Mar	3.08
13-Mar	3.08
14-Mar	2.99
15-Mar	2.97
16-Mar	2.88
17-Mar	3.04
18-Mar	3.08
19-Mar	3.10
20-Mar	3.20
21-Mar	3.20
22-Mar	3.25
23-Mar	3.43
24-Mar	3.49
25-Mar	3.57
26-Mar	3.65
27-Mar	3.75
28-Mar	3.92
29-Mar	4.12
30-Mar	4.31
31-Mar	4.51
01-Apr	4.82
02-Apr	4.92
03-Apr	4.98
04-Apr	5.28

05-Apr	5.35
06-Apr	5.25
07-Apr	5.28
08-Apr	5.41
09-Apr	5.61
10-Apr	5.59
11-Apr	5.09
12-Apr	4.83
13-Apr	4.87
14-Apr	5.15
15-Apr	5.30
16-Apr	4.91
17-Apr	4.65
18-Apr	4.87
19-Apr	5.02
20-Apr	5.43
21-Apr	5.90
22-Apr	6.58
23-Apr	6.80
24-Apr	6.94
25-Apr	6.43
26-Apr	5.98
27-Apr	5.82
28-Apr	5.85
29-Apr	6.00
30-Apr	6.65
01-May	7.22
02-May	7.41
03-May	7.57
04-May	7.44
05-May	7.39
06-May	7.13
07-May	7.30
08-May	7.53
09-May	7.67
10-May	7.85
11-May	8.30
12-May	8.66
13-May	9.33
14-May	10.51
15-May	10.28
16-May	10.28
17-May	10.16

18-May	9.83
19-May	9.92
20-May	10.68
21-May	11.23
22-May	11.50
23-May	11.55
24-May	11.51
25-May	11.41
26-May	11.54